THE

LARYNGOSCOPE.

VOL. XXII. ST. LOUIS, JUNE, 1912. No. 6.

ORIGINAL COMMUNICATIONS.

(Original Communications are received with the understanding that they are contributed exclusively to THE LARYNGOSCOPE.)

MENINGITIS.

Nature. Cause, Diagnosis and Principles of Surgical Relief. (An Experimental and Critical Study.*)

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*MOTTO—"Medical Science is not advanced so much by the observation of facts as by their co ordination. A fact discovered, for which there is no gaping category ready, is a still-born child. * * Yet in adducing proof of a process it is, in the last analysis, only new deductions from facts, and these may be old or new."*—JONATHAN WRIGHT, in *New York Medical Journal*, October, 1911.

PREFACE.

In these pages there is presented a study of certain fundamental factors concerning meningitis—a disease which still offers many unsolved aspects for scientific inquiry.

Progress in the study of the problems presented in meningitis has, heretofore, been achieved mostly along the lines which brought aid in resisting, restricting and overcoming the invasion of the central nervous system by pathogenic micro-organisms. Even at the best progress along these lines has been of limited value—as is seen when the mortality of meningitis is studied.

In this paper, which resolves itself into a consideration of a series of closely interwoven problems, the tissue reactions are more particularly investigated, presenting an aspect of meningitis which heretofore has not received merited attention.

This paper—which is the first of what is hoped will be an interesting series, as the results obtained from further investigation take form and warrant publication—is concerned in the consideration of the following items and problems of meningitis:

*Awarded the Prize for Research, by the American Laryngological, Rhinological and Otological Society, 1912, and presented at the meeting of the Society in Philadelphia, on May 14, 1912.

The writer acknowledges his indebtedness and expresses his thanks for the many courtesies received at the hands of Professor Silas P. Beebe, of Cornell University Medical College, and to Doctor John J. Connellan, for making exact chemical estimations of percentages of fat in spinal fluid to check up the writer's approximate determinations; thanks are also due to Dr. Ernesto Di Mascio for assistance in making up re-agents and control in the identification of the cholin in the spinal fluid.

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I.

INTRODUCTION.

That which we, as clinicians, differentiate as separate and distinct forms of meningitides, each a definite entity, represents in reality a number of conditions which are fundamentally similar, and to some extent progressive in type.

It is at once conceded that each of the so-called types must be, at times, considered separately, but to arrive at a satisfactory understanding of the nature and causation of that which we include in the clinical term,—"meningitis,"—the study must concern itself primarily with a disentanglement and interpretation of those common factors which are found in all meningitides.

Heretofore, we have largely given ourselves up to the discussion of parts of meningitis, considering each part as a separate, distinct disease, classifying and handling it, according to the preponderance of certain exhibited factors. Thus, for example, we have studied it as an entity, when we found meningeal inflammation, as the result of a meningeal tissue-reaction to a definite, invading micro-organism,—the meningococcus,—or we have classified it, and handled it in our text-books and periodicals, as a definite entity when we found it, the result and sequela of a given disease,—otitic meningitis. Furthermore, we have attempted the study of meningitis, without co-relation of its salient feature in each so-called type, basing our classification and treatment entirely on anatomic-pathological standpoints,—pachymeningitis externa, pachymeningitis interna, meningitis basilaris, lepto-meningitis, encephalitis, etc. Finally, as we noted its ravages, in the department of pathology, to be localized, or diffuse, purulent or serous, etc., we again reclassified it and attempted to deal with the multitude of problems these conditions presented. But always the effort has been to keep within the bounds of the given entity.

We have failed heretofore to perceive that all these were phases of one disease,—the abnormal reaction of the tissues which constitute the investing membrane of the brain and the spinal cord, and to some extent the surface of the brain itself. This inflammatory reaction may be produced by different causal agents, brought to the parts through divers channels, in other words, the invading micro-organism and the mechanics of invasion may differ in the various types of meningitides, but the effects are characteristically similar in the tissues effected, and they produce symptoms common to the tissues which are diseased, modified to some extent by the nature

of the invading organisms and the number introduced. This much is fundamental.

If we take position with Adami, and hold that for every structure, and for every function, and for the body as a whole, there is a certain mode, within confessedly vague limits of which conditions are to be regarded as normal, it follows that anything outside the limits on either side, is abnormal, and it is these conditions of excess or defect that for us, constitute disease.

In no region of the body is there so much obscurity as exists on the question of the normal function of the meninges and the cerebro-spinal fluid, and only recently has even an attempt been made to study normal cerebral metabolism, granted that such research presents many seemingly unsurmountable obstacles, yet in our study of the pathology of the parts, as elsewhere in the body, we must base our conclusions upon physiological data, as far as this throws light upon disturbed functional activity; then only, when the abnormal functionation is recognized, the features standing in causal relationship to this disturbance of function become clearer, and a solution of the problem confronting us is in view.

The symptoms of a disease are the visible expression of disturbed functional activity of the parts affected by the lesion, and in the succeeding pages we base our study primarily on the symptoms presented by meningitides.

An endeavor is made in the succeeding pages to outline the knowledge gained on these points, to analyze and disentangle the complex clinical picture presented by the many so-called types of meningitides, and to search for common factors obtainable in all. An attempt is made to show that the most marked symptoms are produced by factors which are common to all the so-called types of meningitides. A reason will be sought for the differing necropsy reports in the study of pathologic data observed at different times during the evolution of a generally progressive disease. Furthermore, attention will be directed to other diseases than meningitides, which nevertheless present so-called "meningeal symptoms" that are in many respects similar to those observed in the disease which is the subject of our investigation. The analysis of these gives a key to the situation in affording an insight into the causation of the symptom-complex of meningitis in most meningeal infections, and it logically points the way to the principals underlying the proposed treatment of the disease.

To render our argument clear, we will at once state our general conclusion:

All the symptoms that characterize meningitis are due fundamentally to common factors, whether the invading bacteria is one or another of the various organisms found standing in causal relationship to the lesion: To the poisoning of the central nervous system by the invasion of microbic organisms and the action of enzymotic ferments plus the products of brain metabolism, which results in an acidosis of the tissues involved, producing an increased tension of the cerebro-spinal fluid with disturbances of its normal circulation.

Finally relief of the symptoms may be accomplished by relieving the heightened intra-cranial tension and combatting the general effects of the action of the poisons on the central nervous system.

We will pass at once to an analysis of the symptomatology that as clinicians we have come to regard as characteristic of meningitides.

The writer takes for granted a general acquaintance with the clinical picture presented by cases of meningitis.

The beginning restlessness and irritability acompanying headache of severe type; the insomnia; anorexia; vomiting; the gradual clouding of the sensorium; the delirium and finally the coma; the irregular pyrexia; the development of the eye-ground picture; the posture of the head on the body, and that of the body as a whole; the Kernig sign; "Tasch cerebri;" Brudzinski and Babinski signs; the Cheyne-Stokes breathing:—all these are signs whose significance is familiar enough to all clinicians.

For the development of our argument, closer study, however, is necessary upon the question of increased intra-cranial tension and its co-relation to the symptom-complex observed in meningitis. To facilitate this study, we first present the experimental and the clinical data bearing on intra-cranial tension *per se,* and as intra-cranial tension is observed in meningitis, and then only endeavor to find and to explain the causes underlying the phenomenon of increased tension.

II.

In this section it is desired to give a short resumé of our scientific knowledge of brain compression, gained from accurate experimentation producing known conditions, then make comparison with unknown conditions produced through infection introduced into the central nervous system, simulating diseased meninges, and finally add to this the study of conditions producing analogous results to brain compression, from bedside observations.

Since, in the evolution of meningitides, the accumulation of cerebro-spinal fluid diminishes the available space within the skull, the observations of Althann, thirty-two years ago, are of moment. He showed that the effect on the brain of diminution of space in the skull was identical with that obtained by any other process which hindered cranial circulation. In other words, the symptoms produced by compression correspond with those of cerebral anemia. Duret demonstrated by injecting wax into the cranial cavity that a diminution of the intra-cranial space by 5 per cent produced somnolence and coma, while 8 per cent resulted in death. W. B. Cannon, in his work on cerebral pressure following trauma, shows that the symptoms preceding death from cranial injury, and the symptoms produced in animals by increased intra-cranial tension, or by otherwise causing cerebral anemia, present striking similarity.

In order to study the specific effects of brain anemia, we conducted the following series of experiments on five dogs. These experiments were undertaken to show other details of which our argument concerns itself, and will be referred to again, under the section dealing with the chemistry of the cerebro-spinal system. They are detailed here because we desire to call attention now to the cerebral anemia and the effects it produces.

In the first place, all our efforts to obtain cerebro-spinal fluid from normal dogs were negative, prior to inducing cerebral anemia. The normal amount of this fluid present in these animals is evidently exceedingly small, and the very fact that such fluid is obtained after inducing anemia alone speaks for increased cerebro-spinal tension. We shall have occasion later to consider the causes of this phenomenon. The creation of new fluid, after opening the cranial vault, although not under conditions which were similar to our experiment, has been amply demonstrated by Spina and Ziegler.

EXPERIMENT No. I.

Dog, No. 560. December 6, 1911: Bull-terrier, 38 lbs.; placed under general ether anesthesia. Puncture of spinal column with small Quincke needle, and animal's head strongly flexed on thorax, and hind-quarters elevated, fails to cause any outflow. Puncture through atlanto-occipital ligament, also negative. Through an incision along medium line of the anterior surface of the neck *both internal carotid arteries are ligated.* Anesthetic withdrawn. One half hour later, dog awake and about.

December 7, 1911: Dog in good condition, but slightly apathetic.

December 8, 1911: Dog in good condition, nothing of moment. Again placed under ether anesthesia, and a ¾-inch trephine opening placed in skull, over cerebrum, in the median line. Dura found exceedingly tense, no pulsations, and pressure evident. A fine hypodermatic needle is in-

troduced under the dura, and without flexture of the head, fluid is withdrawn, and marked for analysis, No. 560.

Dog killed with chloroform.

In order to make further observations on the effects of anemia, note the time of the onset of the anemia-effect, and incidentally to study the "duration-effect," another experiment was conducted as follows:

EXPERIMENT No. 2.

December 8, 1911: Brown mongrel dog, 25 lbs.; placed under general ether anesthesia. Trephine opening made in skull, same as in experiment No. 1. Dura and brain and blood-vessels found under normal tension. Dura is not incised. The ligature of *both internal carotid arteries* performed. Dura gradually becomes tense and evidence of intra-cranial pressure given to the touch. At the end of one hour button of bone is replaced and skin sutured, and scalp sutured over it. One-half hour later, dog recovered from anesthesia.

December 11, 1911: Wound examined. The intra-cranial pressure was great enough to push out button of bone, and press dura and brain into the trephine opening. The dura was dirty red, and gangrenous looking. A small incision through the dura afforded egress to a considerable quantity of cerebro-spinal fluid. Dog killed with chloroform.

To carry out a similar experiment, but prolong the period of observation, similar procedures were again undertaken, and a month's interval allowed before observation, and examination of the fluid and the blood.

EXPERIMENT No. 3.

December 20, 1911: Boston bull-terrier, 50 lbs.; marked No. 577; placed under general ether anesthesia, and both internal carotid arteries ligated. Dog kept under observation, found slightly apathetic at first, but soon he was eating, running about and, in general, functionating normally. On January 15, 1912, he was again narcotized, cerebro-spinal fluid drawn and marked No. 577. A trephine opening was placed in the skull. Marked intra-cranial tension demonstrable, but before measurements could be taken dog died under anesthesia. Whether the prolonged cerebral anemia contributed to death during the second experiment could not be determined. Autopsy revealed flattened convolutions of the brain and marked constriction of all the arteries. The absence of any punctate hemorrhages in the brain was noteworthy in a death occurring under anesthesia.

To study increased intra-cranial tension in another manner, the following experiments were performed, the idea being that increased tension would manifest itself as a brain hernia,—the time of its formation, and the height of its protuberance being taken as standards for measurements and comparison with the normal.

EXPERIMENT No. 4.

December 20, 1911: Mongrel black setter, 40 lbs.; placed under general ether anesthesia, and both *internal carotid arteries*, and the right internal jugular vein ligated. Dog observed daily and found to present nothing unusual until end of one month.

January 20, 1912: Trephine opening placed in skull over cerebrum. Blood and fluid drawn and examined. Dura found very tense, no pulsations. A crucial incision one inch in diameter placed in the dura in the center of the trephine opening. Within five minutes a hernia cerebri had formed, ¾ of an inch in height, measured exactly by calipers. The formation of the hernia began immediately after the dural incision and it reached its height in 4.5 minutes. Observation was continued a half hour longer, no change observed, and then dog was killed with chloroform.

In order to study the normal phenomenon, and also to observe whether hernia cerebri would form in the opened cranial vault without anemia-pressure symptoms, and to obtain normal fluid and blood for examination, the following experiment was performed:

EXPERIMENT No. 5.

January 15, 1912: Mongrel medium-sized dog; marked No. 579; placed under general anesthesia, and skull trephined over cerebrum as in the previous experiments. No tension evident. Puncture of sub-arachnoidal space and the sinus for fluid and blood performed. Very little fluid obtained with aspirating needle. Dura now incised by crucial incision one inch in diameter. Watched for 30 minutes, *no brain hernia formed.* The dog turned on his back and *both internal carotid* arteries separated out and ligatures thrown around them, but not ligated at this time. Dog again fastened in observation position and watched one-half hour longer. *No hernia cerebri evident.* At the end of second half-hour the ligatures previously placed about the internal carotids, are closed, tying off the two arteries. Immediately, a hernia cerebri begins to form, increased tension at once becoming evident. The hernia reaches a maximum growth in five minutes. Fluid and blood again drawn and marked for analysis. Dog observed one hour longer, no change noted, then killed with chloroform.

From all these experiments it is evident:—that anemia of the brain produces increased tension, which rapidly reaches its maximum effect; that the increased tension is as likely to be produced by depriving the parts of their normal arterial supply of blood as by a venous stasis. In other words, whether in a given case, the anemia of the brain-tissue is produced directly by interference with the arterial blood-supply, or whether because of an abnormal increase in the amount of cerebro-spinal fluid present in the given intra-cranial space, the effect is the same, viz.: a compressed blood-supply is the prime factor. To the causes underlying these phe-

nomena we shall have occasion to refer below, when we detail the results of our analyses.

It is conceded that the brain is incompressible, the cranial vault is unyielding, and space in the skull becomes available only by displacement of the cerebro-spinal fluid and compression of the blood supply of the brain.

The respiratory and cardiac impulses, producing the pulsations of the brain, are the regulatory mechanism in the circulation of the cerebro-spinal fluid. The maintenance of a correct balance between the fluid and the blood-supply,—more particularly the venous blood supply—regulates the relative size of the brain and the amount of fluid surrounding it. An interference with the venous outflow will produce a disturbance in the normal tension of the cerebro-spinal fluid, and the changed tension results in varying the tension with which the blood is forced through the tissues of the brain.

That even *extra-cranial obstruction* to the venous outflow from the brain will produce such a disturbed relationship in the balance between cranial blood supply and cerebro-spinal fluid circulation is evidenced to Edward Archibald, by tinnitus, dizziness, headache, insomnia, with slight visual disturbances in cases of retro-sternal goiter and thoracic tumors. Further clinical analogy is found in the observation of Cushing, who saw that when the brain-surface is laid free, the dura being opened,—and thereafter the jugular veins are compressed, without compression being made on the lymphatics of the neck—that the brain not only swells up but there is *at once* evident an increased amount of cerebro-spinal fluid, because the way for the "outflow" of the fluid is hindered.

The phenomenon is much too sharp, and happens much too quickly to be ascribed to a new creation of fluid, but rather it must be ascribed to the obstacles placed in the way of the outflow of the circulation.

From this it is apparent that a *stasis* in the cerebro-spinal fluid circulation is capable of exerting in the unopened skull a very considerable amount of pressure.

When the cranial circulation is obstructed *intra-cranially* and the venous outflow is obstructed as far as the capillaries, every anatomical side-path for the outflow of the venous blood is occluded,—the emissaries, the ophthalmics, the facial veins, and even the anastomoses of the spinal plexus of veins—and, in addition, we know from the experimental work of Leonard Hill and Harvey Cushing, the medulla and cerebellum are forced down upon the foramen magnum and thus shut off the escape of spinal fluid from the skull into the spinal column.

Before proceeding further in our discussion of the phenomenon of intra-cranial tension, the essential physiological facts necessary to the comprehension of the experimental work must be detailed.

Speaking in the broadest possible sense, life is absolutely dependent on the function of three vital centers located in the floor of the fourth ventricle. It is these three centers which are mostly affected and whose reactions to intra-cranial tension plays the most important part in the clinical manifestations of increased cranial tension. These three centers are the vaso-motor, the vagus or cardiac inhibitory, and the respiratory center.

Among other functions, the vaso-motor center influences and controls the blood-pressure through its effect on the arteries. The vagus, stimulated, slows the heart-beat and in this way slightly tends to reduce blood-pressure, while the respiratory center, controlling respiration, is necessarily under the influence of the two other centers, because it is markedly influenced by the quality of blood flowing through it.

While it might be desirable from an historical standpoint to follow each step in the attainment of our knowledge of the physiology of brain-compression, the space and scope of this paper forbids such details. One may mention, among a host of others, the names of those whose painstaking labors have won for us this information; among these, the names of Althann, Leyden, Falkenheim and Naunyn, Duret, Manz, Pagenstecher, Bastigen, Couty, Markwald, v. Bergmann, Cramer, Adamkiewicz, Roncali, Horsley, Spencer, Elden, Francois Franck, Ziegler, Spina, Cannon, Hill, Kocher and Harvey Cushing. It suffices for our purposes to sum up the present status of our scientific knowledge, as given by Kocher and his pupils, and as found in the classical work of Harvey Cushing.

To correlate the phenomenon of brain-compression, and in order to study its varying phases at first hand, the writer repeated in detail, in December, 1910, the experiments of Cushing in regard to the phenomenon of general brain-compression, by injecting into the cerebro-spinal system physiological salt-solution under conditions of graduated and measured pressure. After a number of preliminary experiments to ascertain the necessary pressure factors, the experiments were conducted at Cornell University, on four dogs exactly as described by Cushing. It becomes unnecessary, therefore, to repeat the description of the work, as Cushing's publications are easily available. Our tracings were taken up in ink on

a stylographic kymograph,* the blood-pressure, and the induced intra-cranial pressure were measured by manometers and automatically recorded, while a third pen wrote the respiratory tracing. At the same time observations were taken and recorded of the picture seen through the glass window placed in the skull, which exposed to view a small section of the sagittal venous sinus, one and a half sulci with their acompanying blood-supply and the greater portion of one convolution.

I was assisted in these experiments by Professor Irving S. Haynes and Dr. Baldwin of Cornell University, and Dr. Chas. J. Imperatori, of my staff.

In every particular the findings of both Kocher and Cushing were checked and verified, and the result of our knowledge can be best stated in the paraphrase of Cushing's conclusion:

1. Under compression, it is noted that the obstruction to the circulation begins on the venous side and extends backwards toward the arterial side. The collapse of the longitudinal sinus, and the condition of stagnation in the pial vessels, evidence the hindrance to venous outflow.

2. The compression-force being constantly increased, very soon after the veins are pressed empty, the capillaries and the smaller arterioles are noted to be in their turn, emptied. This produces a condition of anemia, and occurs exactly at the moment when the degree of compression *exceeds* the degree of blood-pressure.

3. To be remembered is the fact that this condition of anemia, although impossible to render visually controllable in the medulla itself, must certainly be present there as well as in the cortical area under the window and in our view,—this anemia stimulates the vaso-motor center, which responds by driving up the degree of blood-pressure above the level to which the compression-pressure has been put. If, now, the latter—the compression-pressure—be further elevated, the same sequence of events is repeated. But whether the compression force be raised still higher or not, there now appears a new phenomenon,—usually a rhythmic activity of the vaso-motor center resulting in the well-known Traube-Herring waves. The blood-pressure curve raises above the compression curve, and the medulla receiving a fresh blood-supply responds in a relaxation of the vaso-motor center, and the blood-pressure again gradually drops beneath the level of the compression force, thus again the anemia is provided which again stimulates the vaso-motor center, which responds by driving up the blood-pressure, and so the

*Mackenzie kymograph modified by Dresser.

cycle is repeated and repeated, and the "fight for existence" is thus waged.

Finally, from Cushing's experiment, and under our own observations, it is noted that if the compression-force be raised the blood-pressure curve follows it upward. This rhythmic activity is to be regarded as the rescuing power of the vaso-motor center.

During the time of these procedures, the effects of the compression-force upon the respiratory and the vagus center are not lacking. Shortly before the compression-force reaches the level of the blood-pressure, respiration becomes slower and more shallow. This corresponds with the stage of venous stagnation while the capillaries still are receiving blood. Shortly afterward, however, during the period of temporary, though complete, anemia of the capillaries and the arteriolar district, respiration completely ceases. With the onset of the Traube-Herring waves, respiration reappears, and continues during the intervals at which blood-pressure exceeds the compression-force. Thus there is developed a very much interrupted respiration which, in its essence, resembles the so-called Cheyn-Stokes type.

The relation of the Cheyne-Stokes respiration to cerebral compression has lately been studied by Eyster. As a result of his observations, he finds that there are several types of disturbed respiratory rhythm. It seems only necessary to impress the fact that disturbances of respiration caused by derangement of the cerebral circulation need not assume the typical Cheyne-Stokes type, but may with equal significance consist merely in an irregularity both of rate and of depth, although usually there will appear some evidence of the periodic character in these disturbances.

To demonstrate the parallelism, or analogy, of experimentally induced, increased intra-cranial tension, and increased tension resulting from infection of the meningeal spaces by pathogenic micro-organisms, and to show that in the latter instance a similar picture is unfolded to the observer through the window placed in the skull, experiments were undertaken along such lines, and, although the results were not as clear-cut as could be wished, because of a number of readily understood circumstances,—the difficulty of infecting the meninges, death of the animals from general sepsis, before the picture was unfolded, or during the performance of the trephine operation, or, again, laceration of the distended and infected meninges when inoculation was successful. Yet finally a set of pictures were obtained which correspond in a rather regular way to those seen in the Cushing experiment.

After various attempts to infect the meninges of dogs, a culture of mixed steptococci and hay bacillus was finally obtained which was found to produce death after infection of the meningeal spaces (only autopsy-microscopical evidence of meningeal infection was considered satisfactory) in from twenty-four to thirty hours in dogs weighing from thirty to forty pounds. For purposes of identification the infecting media is designated emulsion *X*, of which one cubic centimeter was used, and repeated in twelve hours.

EXPERIMENT No. 6.

December 10, 1910: Dog No. 2; Cornell University, 5:30 p. m. Under general anesthesia, trephine opening made in skull and, after incising dura on one side of the median line and turning back the dural flap bringing three small convolutions into view, emulsion *X*, one cubic centimeter, was injected into the sub-dural space.

The window was then sealed into position into the trephine opening. A quilt suture was taken above and below the window through the skin and scalp to cause a clear view of the window from the outside. A dressing was put over all, and dog permitted to emerge from the anesthetic. Observation that evening showed nothing noteworthy.

December 11, 1910: At 11 a. m. a small Quincke needle is placed through the atlanto-occipital ligament into the sub-dural space, and about one cubic centimeter of cerebro-spinal fluid is obtained—marked I—for examination. The finding of any fluid at all spoke for an increased tension, for in all the controls we were never able to obtain a spontaneous flow with the needle similarly placed and at most could only get one or two drops. In the experiment here described this fluid was obtained without resort to flexing the dog's head on his thorax and without resorting to the procedure of raising his hind quarters and compressing his abdomen. Now a second injection of emulsion *X* (1. ccm.) was given through the needle.

12:45 p. m.: Observation through the window. Three convolutions in view. No dural or brain pulsations evident. Surface of brain rather hyperemic-looking; capillaries and pial vessels injected, small veins well marked, small arteries dilated, the longitudinal sinus, however, shows evidences of pressure, it is flattened against the glass and has lost its blue color. Pulse so fast as not to be countable. Respiration, irregular, 27 per minute. Temperature, 102.2°. Dura on unopened side red and discolored.

No rapid change from anemia to injected blood-vessels was observed. The pressure-increase was too gradual, perhaps, and the instantaneous changes were not sufficiently distinct to be observed by me so as to be recorded. The pauses in the respiration—periodicity—were evident from time to time.

6:15 p. m.: Dog breathing in gasps. Pupils dilated and not reacting to light. Dog unconscious, reflexes abolished in eye (touch). The intra-cranial tension was great enough to expel the window from the skull. Window replaced. Observation continued. Now was seen a rapid

change. During a period of irregular respiration—with long "sighs"—the capillaries were observed dilated, and then emptied. The larger veins were about the same as observed in the morning. Dog died at 11:10 p. m.

***Autopsy*: Macroscopically no lesion evident in dura or in brain, except a few small hemorrhagic spots in meshes of pia. Ventricles moderately dilated. A few punctate hemorrhages in the brain substance.**

Microscopically, the meninges show evidence of an acute infection. Agar slant from cerebro-spinal fluid drawn December 11, 1910, at noon and marked I, shows predominating organism to be streptococci. The hay bacillus not recovered from specimen.

It is conceded that this picture leaves much to be desired as evidencing the continual play between the vaso-motor, the vagus, and the respiratory centers, yet this, and the fragmentary pictures we received from repetition of this experiment, is enough for our conclusion that similar conditions result from infection of the meninges to those shown to ensue upon inducing experimentally increased intra-cranial tension, and we feel justified in assuming the existence of a parallelism in the symptomatology of artificially induced intra-cranial tension, and the increased pressure intra-cranially present when the meningeal spaces are infected by micro-organisms. We feel this parallelism justified the more because, although it was and is assumed by clinicians to exist, it has heretofore never been scientifically proved. In addition, we adduce the following evidence:

During constriction of the neck, Bordly, working in conjunction with Cushing, was enabled to see, using an ophthalmoscope, very definite venous stasis at a manometric pressure of 80 mm. of Hg. This stasis becomes very considerable at 120-140 mm. of Hg.—i. e., at the level of blood-pressure. The stasis at blood-pressure is accompanied by dizziness, nausea, and stupor, all of which rapidly pass off when the constriction of the neck is removed.

Further, an observation by Cushing and Bordley presents additional data. In a patient suffering from a posterior basic meningitis, which obstructed the foramina of the fourth ventricle, and produced an acute internal pyohydrocephalus, the increased intra-cranial tension produced marked compression symptoms. The ventricles were tapped, and during the procedure Bordley, following closely with the ophthalmoscope the condition of the veins radiating toward the papilla, reports as follows:—"Immediately on removal of the ventricular fluid the veins, which had been tortuous and much engorged, became smaller in caliber, and lost much of their sinuous outline, while on the other hand the arteries became larger, more prominent, and seemingly more tortuous." This case further

verifies from the clinical standpoint the observations which von Schultèn made on rabbits, during the first stages of brain compression, where the picture observed in the fundus of the eye is found really to be an edema of the papilla which is apt to disappear later in the course of the compression. This edema of the papilla must not be confounded with the "Stauungspupile," or choked disc, which belongs more properly to prolonged compression. The condition is the result of the forced entrance of cerebro-spinal fluid under the influence of increased intra-cranial tension into the sheath of the optic nerve at the entrance of the latter to the orbit. The explanation of the phenomenon is as follows: The cerebro-spinal fluid exercised upon the blood-vessels of the optic nerve a strangulation effect. The effects of a strangulation of the blood-vessels in the production of edema will receive consideration in the section which follows (Section III). Here it is sufficient to state that the edema of the papilla is not dependent on an obstruction of venous circulation in the cavernous sinus, and it is further noteworthy that it disappears as soon as the excess of cerebro-spinal fluid is reabsorbed from the cranial cavity. When the cerebro-spinal fluid remains for a longer period, in this locality, compressing the vessels of the optic nerve, then the simple edema give way to the pathologic signs of inflammation with the result that a typical choked disc of optic neuritis becomes evident. The writer has repeatedly observed this papillitis in the early stage of meningitis some time before any other sign or symptom was present, excepting intense headache. It is not always equally present in both eyes, and in many cases ophthalmologists have reported its occurrence to the writer in examining the eye-grounds of such cases, without indicating in any way a knowledge of its significance.

Finally, additional factors are adduced to show the existence of increased intra-cranial tension in meningitis, and complete the analogy between the experimentally produced, known condition of brain-compression with its train of symptoms, and the same train of symptoms exhibited by the infected meningeal membranes. Such a study of symptomatology must perforce take place at the bedside, and must be concluded by a study of the necropsy reports of cases thus studied.

In man it is naturally impossible exactly to measure the degree to which the brain is compressed. It is, furthermore, impossible to open a main vessel and record an actual reading of the blood-pressure. But, by using any one of a number of instruments now available for such purposes, an approximate estimation of the

blood-pressure is obtainable, and although the parallelism with experimental findings is not so clear in the case of the respiration and vagus centers as it is in the case of the vaso-motor center, yet if the clinical observation be keen enough it will frequently be found to run in complete analogy with the findings from the experimental laboratory.

In experimental studies, the rhythmic activity of the vaso-motor center is evidenced early and very plainly in an alternate arrest and resumption of respiration. In the human subject this differs slightly. Where, clinically, the degree of compression is moderate, the vaso-motor center works rhythmically, producing Traube-Hering waves, although the respiration will often continue regular both in regard to rate and depth. With high degrees of compression, close observation shows the respiration affected in the sense of its being irregular and slowed up at the bottom of the crest and exhibiting almost normal breathing at the top of the wave instead of complete arrest as in experimental work. As the compression increases further the irregularity becomes more and more marked until, with the onset of a severe degree of compression, typical Cheyne-Stokes breathing is noted. It would be a mistake, in moderate compression seen at the bedside, to expect typical Cheyne-Stokes breathing, yet when the latter does develop it is easy enough to determine, by means of a blood-pressure manometer, that the period of respiratory activity corresponds fairly well with the rise of the blood-pressure curve and that the apnea is simultaneous with its drop.

Eyster was the first to present an accurate and continuous record of blood-pressure and respiration in the human being under conditions of cerebral compression. This he did in a case of tuberculous meningitis, in which compression became marked and typical Cheyne-Stokes respirations developed. Eyster demonstrated that great variations might occur in the derangement of the respiratory action under compression. He finds four distinct types:

(a) Groups of respirations of approximately equal depth.

(b) Descending groups in which inspiration was largest.

(c) Groups of irregularity, especially in depth.

(d) Groups of typical Cheyne-Stokes breathing of both ascending and descending types.

He confirms the general observation that the groups of respiration are associated with a rise in blood-pressure and an increase in the pulse rate, whilst the periods of apnea were simultaneous with a fall in the blood-pressure and a general slowing up of the pulse

rate. Moreover, with the disappearance of the periodicity of respiration there was also shown a disappearance of the blood-pressure wave and a variation of the pulse-rate.

During apnea the pupils dilated, the eye-balls rotated outward and upward, and the patient became unconscious. During periods of respiration the pupils returned to their former size and consciousness returned. These phenomena were also found to co-incide with the rise and fall of the blood-pressure waves. Trotter has fully substantiated these observations, and since our more intimate acquaintance with them the writer has been able, upon different occasions, to observe at the bedside both the periodicity in the depths of the unconsciousness, and its coincidence with the varying size of the pupils.

There are a few other recorded observations on blood-pressure taken at the bedside, but these mostly fail to have scientific value, because they are isolated records, rather than continuous readings taken at small intervals of time during the entire course of the disease under observation. Thus, Hubby gives a somewhat extensive study of the blood-pressure in cases of intra-cranial disease, and while his work is open to the general criticism given above, his evidence on the whole shows that increased tension was presented when the cases gave active symptoms of meningeal involvement. Robinson finds that heightened intra-cranial tension appears to be an almost constant phenomenon in epidemic cerebro-spinal meningitis. Heightened blood-pressure of a moderate degree he finds even in the early acute stages of the disease. The blood-pressure seems to bear some relationship to the severity of the disease, being higher when the symptoms are severe and low during convalescence.

In a case which the writer observed with Dr. R. J. Held he watched the gradually mounting blood-pressure as the meningitis developed. In this case the intra-cranial tension was so great that at the exploratory operation (decompression operation) performed by Dr. R. Johnston Held, the brain substance, after incision of the dura, sprang forth into the wound cavity, producing a hernia cerebri, exactly similar to the formation of such hernia cerebri observed in the experimental work on dogs, detailed above.

If we study the bedside case further, as it nears its fatal termination, additional parallelism between the experimental findings in brain-compression and the tension of meningitides is observable.

In most cases of meningitides death is seen as result of vaso-mo-

tor paralysis, the observations of Victor Horsley to the contrary, notwithstanding. When the vaso-motor center can no longer succeed in forcing blood into the medulla, the effects are first noticeable in the respiratory center, yet the vaso-motor center is primarily at fault. Druif, in spite of continuing very high cerebral compression, was unable to bring about death in his animals so long as he kept up artificial respiration; and in clinical cases artificial respiration has kept the heart going for long periods,—in one of Cushing's cases it persisted thus for twenty-four hours after the vaso-motor center had given out. In a case observed by the writer, the heart-beat of a young male adult—in a case of purulent otitic meningitis—was kept going strongly for almost an hour, artificial respiration being kept up by the writer, members of the house-staff and nurses working the artificial respiration movements in relays. In this case the heart only ceased beating when the artificial respiration was stopped, which was done when the stethoscope demonstrated the advent of the pulmonary edema of death, and it was no longer possible to force air into the lungs.

Finally, the existence of excessive increase of fluid is shown by the results of repeated lumbar punctures in these cases, and also from the records of necropsy findings recorded in literature, which narrate the story of distended ventricles and the presence of excessive exudate in the meshes of the investing membranes of the brain. All this evidence goes to show the increased tension of the spinal fluid as a dominating factor in meningitides.

The best set of such reports, easily available, containing detailed case-histories with operative findings and post-mortem, gross and microscopical examinations, are to be found in the classical collections gathered and published by Koerner in his book, and further added to in his "Nachtraege," published in 1908, to which the reader is referred.

From this mass of material the writer will select cases to illustrate the progressive nature of meningitis, when discussing that topic below; now it is of moment simply to point out that these reports give ample material to substantiate our contentions regarding the existence of an increased tension of the cerebro-spinal fluid in these cases.

From the evidence thus far adduced we may summarize as follows:

1. That there is an analogy in the symptoms exhibited by brain compression, and by those brought on by meningeal tissue reactions to microbic infection.

2. That the infection of the central nervous system, particularly in the investing membranes of the brain, results in an increase in the tension of the cerebro-spinal fluid with functional disturbances of the vagus, the vaso-motor and the respiratory centers.

3. That these symptoms dominate the clinical picture of meningitides, modified to some extent by other factors, hereinafter to be discussed.

4. That evidence of the increasing tension is obtainable by repeated manometric measurement of the blood-pressure, by the systematic and repeated study of the fundus of the eye, the results of lumbar puncture, and a keen observation of the character and rate of the respiration at the bedside.

III.

In the previous section an endeavor is made to show the effect of increased tension of the cerebro-spinal fluid and the production of the pressure symptoms in the clinical picture. In doing this certain factors were advisedly left out of the discussion which, in themselves, are of importance as assisting in causing the increased tension. These factors are now to be considered.

To render comprehension of the argument easier the statement of the principal problem is given first, followed by the evidence upon which the conclusions are based:

In the production of increased tension of the cerebro-spinal fluid the edema of the brain-tissue itself, in addition to an edema of the tissues of the investing membrane, is the principal factor. The former impinges on the available space in the cranial vault, and the latter additionally interferes with the free circulation of the cerebro-spinal fluid.

In order to understand the problem of cerebral and meningeal edema a study of some fundamental principals of edema are in order.

We observed, from the writer's experiments detailed in Section II, that when the dura of the dog was exposed and incised an interference with its blood supply (arterial) by ligation of the internal carotid arteries produced an edema sufficient to cause a hernia cerebri within the space of time amounting to five minutes.

control experiments not acting similarly when the arterial blood-supply remained intact. We have, furthermore, seen from the observations of von Schulten, regarding the edema of the papilla of the eye, that the strangulation effects of the cerebro-spinal fluid on the arterial blood vessels in the sheath of the optic nerve was the cause assigned for the edema of the papilla. Cannon's observations furnish additional evidence of the ability of the brain to absorb water and produce an edema great enough to shut off its own arterial blood-supply—observations which our own experiments on dogs fully substantiated.

These observations pave the way for the conception of edema from the standpoint of bio-chemistry, and as proving that the swelling of the brain is produced independently of the blood-pressure through this organ, and often in spite of the blood-pressure.

For this conception of edema we are indebted to the brilliant research work of Martin H. Fischer.

For purposes of bio-chemistry the body tissues are a collection of colloids, and for our discussion it is important to bear in mind that these colloids react definitely to the fluid media bathing them.

Martin H. Fischer has satisfactorily shown *that the cause of edema resides in the tissues themselves.* He says "A state of edema is induced whenever, in the presence of an adequate supply of water, the affinity of the colloids of the tissues for water is increased above what we are pleased to call normal. The *accumulation of acids within the tissues brought about either through their abnormal production, or through the inadequate removal* of such, as some consider normally produced in the tissues, is chiefly responsible for this increase in the affinity of the colloids for water, though the possibility of explaining at least some of the increased affinity for water through the production or accumulation of substances which affect the colloids in a way similar to acids, or through the conversion of colloids having but little affinity for water into such as have a greater affinity, must also be borne in mind."* He further states that "every condition that makes for a state of lack of oxygen in the edematous parts * * * makes for an increase in the severity of the edema."

Upon this question the following observations throw light: Araki has shown that dogs, rabbits and frogs excrete lactic acid in the urine in addition to other abnormal substances when they are sub-

*Italics are mine.

jected to lack of oxygen. Hoppe-Seyler's analysis of various edema fluids was found to contain many acids—lactic, valerianic, succinic and butyric acids. The lactic acid found in conditions associated with lack of oxygen *is produced in the tissues.* This is further substantiated by Zillessen's experiments, who found that when the oxygen supply to a muscle, or to the liver, is shut off a variable length of time an increased production of lactic acid takes place.

The interference with the blood-supply, the prevention of proper oxygenation, means the accumulation of carbon dioxide in the tissues, and from the observations of Strassburg and Ewald it is seen that the carbon dioxide contents of edema fluids and tissues deprived of a circulation runs very high, and is another cause for the affinity for water (Cited by Fischer).*

To determine the question as to whether or not an acidity could be found in the cerebro-spinal fluid, analysis of the fluid were undertaken, and the findings are herewith presented.

Cerebro-spinal fluid was examined as to its reaction to sensitive litmus paper. A measured quantity was then titrated against n/10 sodium hydroxide solution and the results given in grain of n/10 hydrochloric acid solution, estimated to the 100 ccm. In each case phenolphthalein† was used as an indicator. In every case a test was also made to determine whether the acidity was "free" or "combined." In no case was "free acidity" obtained. The bearing of "free acidity" and "combined acidity" on colloidal reactions will receive attention below.

Our analysis comprised thirty-six fluids from cases of meningitis and cases which gave meningeal symptoms, but were not true meningitides. We also obtained some normal cerebro-spinal fluid from lumbar puncture from a case of excessive auditory tinnitus, where the removal of the fluid was performed to relieve the tinnitus. In addition, normal fluid was also obtained through the courtesy of Dr. M. D. Kaplan of the Neurological Institute, New York City, from cases of nervous diseases other than meningitis. Thus the writer was in possession of ample material to act as controls for his observations detailed in Table I.

*The entire process of reasoning and experimentation by which Fischer arrives at his conclusions would demand too much space to be here repeated. His work is full of references and experimental findings, and will amply repay perusal.

†Phenol-phthalein 1 gram. Alochol 50. Water q. s. a d. 50.

TABLE 1.

No.	Clinical Diagnosis	Free Acidity	Reaction to Litmus	Degree of acidity in terms of n/10 HCl solution in 100 ccm. of fluid
38	Tuberculous meningitis...	neg.	neutral	0.03618 or 3.6%
40	Purulent (otitic) meningitis	neg.	neutral	0.01809 or 1.8%
41	Anterior poliomyelitis ...	neg.	neutral	0.72236 or 7.2%
42	Meningococcus meningitis.	neg.	faintly acid	0.50652 or 5.0%
43	Normal fluid	neg.	neutral	Alkaline
45	Anterior poliomyelitis	plus (?)	faintly acid	0.578879 or 57.8%
46	Tuberculous meningitis ..	neg.	neutral	0.028944 or 2.8%
47	Tuberculous meningitis ..	neg.	neutral	0.028944 or 2.8%
48	Tubercle of cerebellum...	neg.	neutral	0.028944 or 2.8%
49	Cerebrospinal rhinorrhea.	neg.	faintly acid	0.028944 or 2.8%
50a	Cerebral embolism**	neg.	neutral	0.07236 or 7.2%
50b	Cerebral embolism	neg.	neutral	0.057888 or 5.7%
50c	Cerebral embolism	neg.	neutral	0.057888 or 5.7%
51	Anterior poliomyelitis ...	neg.	neutral	0.07236 or 7.2%
54	Purulent (otitic) meningitis	neg.	neutral	0.047034 or 4.7%
55	Anterior poliomyelitis ...	neg.	neutral	0.021908 or 2.1%
56	Idiocy amaurotic type....	neg.	neutral	0.0094068 or 0.9%
57	Purulent (otitic) meningitis	neg.	neutral	0.028944 or 2.8%
58	Cerebral embolism ** after recovery of symptoms	neg.	neutral	0.0037888 or 0.3%
59	Tuberculous meningitis hydrocephalus	neg.	neutral	Alkaline
60	Tuberculous meningitis (acute case)	neg.	neutral	0.010854 or 1.0%
61	Chronic hydrocephalus ..	neg.	neutral	Alkaline
62	Chronic hydrocephalus ..	neg.	neutral	Alkaline
63	Meningeal symptoms following resection of Int. jugular. No real meningitis	neg.	neutral	Alkaline
64	Otitic sepsis with meningeal symptoms. No meningitis	neg.	neutral	Alkaline
65	Normal fluid	neg.	neutral	Alkaline
65a	Meningococcic meningitis.	neg.	neutral	0.010854 or 1.0%
67	Meningococcic meningitis one week after improvement set in. Patient now conscious	neg.	neutral	Alkaline
68	Tuberculous meningitis ..	neg.	neutral	0.01809 or 1.8%
69	Tuberculous meningitis ..	neg	neutral	0.028944 or 2.8%
70	Meningococcic meningitis.	neg.	neutral	0.03618 or 3.6%
71	Meningococcic meningitis.	neg.	neutral	0.03618 or 3.6%
72	Chronic hydrocephalus ..	neg.	neutral	0.0123012 or 1.2%
73	Fulminating type, purulent otitic meningitis..	neg.	neutral	0.03618 or 3.6%
74	Meningism accompanying scarlet fever	neg.	neutral	0.03618 or 3.6%
75	Tuberculous meningitis ..	neg.	neutral	0.07236 or 7.2%

The finding is untrustworthy as free acidity was found and upon tests to determine its nature free hydrochloric acid was found, probably uncleanliness in beaker.

**This case seen by the writer was thus diagnosed. As recovery took place, definite diagnosis is still an open question. During high degree of meningeal symptoms fluids were examined, fluids Numbers 50, 50a, 50b, 50c,—twenty-four hours apart. Fulid 58, few days later, when meningeal symptoms had almost disappeared.

It is seen from the above analysis that the cerebro-spinal fluid was alkaline or amphoteric in fluids obtained from cases which were normal as regards the meninges, or were not acutely inflammatory. On the other hand, all the fluids obtained from cases of meningitides and other diseases giving bulbar symptoms similar to pressure symptoms, presented an acidity of varying degree.

V. Jaksch has shown that the normal alkalinity of the cerebro-spinal fluid is equal to 20 ccm. of a n/10 acid solution. If we estimate this alkalinity in terms of n/10 sodium hydroxide solution it would be found to be equal to 0.07952 grams in 100 ccm. of fluid, or 7.9 per cent. The difference between this amount of alkalinity and the amount of acidity found by the writer in diseased conditions of the meninges, etc., is very striking.

In connection with this study of the reaction of the cerebro-spinal fluid it is interesting to note the observations made by Andrew Connell, who examined 1000 specimens of fluid. He finds that the fluid maintains its alkalinity in all specimens he examined, but he acknowledges that the degree of alkalinity varies according to the nature and the degree of the meningitis. From his examination he concludes that the normal fluid possesses the highest, and the turbid fluid in the earlier stages of acute pyogenic meningitis the lowest degree of alkalinity. The reactions of fluids from cases of tuberculous meningitis were also found to be uniformly alkalin, *but distinctly less so than normal.**

In criticising these observations it is to be noted that Connell unfortunately failed to make exact estimations of the degree of alkalinity presented in terms of known acidity as is usual in chemical estimations, nor does he state how soon after the withdrawal from the body were the examinations into reaction undertaken.

That the spinal fluid undergoes change—autolytic—and other changes due to the growth in it of microbes, must be apparent to all. The following experiments show how such changes affect the reaction and its estimation:

EXPERIMENT No. 7.

On December 28, 1911: Fluid was withdrawn from a case clinically diagnosed as tuberculous meningitis. It was found to be alkaline (not neutral) to litmus, and alkaline to phenol-phthalein solution. The fluid was kept at room temperature to December 31, 1911, when its reactions were taken and it was found to be neutral to litmus and *acid* to phenol-phthalein solution. This acidity was equal to 0.04318 grams of n/10

*Italics are mine.

HCl solution in 100 ccm. of fluid. The fluid was kept open to the air, at room temperature, until January 2, 1912, when its reactions were again found alkaline to litmus and to phenol-phthalein. Meanwhile it had become cloudy from infection from the air, where previously it was clear.

EXPERIMENT No. 8.

Fluid No. 70: Examined on February 9, 1912, and found to possess an acidity equal to 0.03618 grams of n/10 HCl in 100 ccm. of fluid. Twenty-four hours later the acidity only equalled 0.010584 grams of n/10 HCl in 100 ccm. of fluid, a reduction in acidity from 3.6% to 1%.

EXPERIMENT No. 9.

Fluid No. 69: Examined on February 9, 1912, showed an acidity equal to 0.028944 grams of n/10 HCl in 100 ccm. of fluid, while 24 hours later the acidity only equaled 0.010854 grams of n/10 HCl in 100 ccm. of fluid —the reduction equalling a fall from 2.8% to 1%.

From these observations it is concluded that in order to obtain a correct estimation of the reaction of the fluid it must be examined as soon as possible after its withdrawal from the body, and if the examination is delayed an allowance should be made to account for the difference in reaction between the time of withdrawal and the time of examination. The examination of all our fluids in regard to this reaction was thus always undertaken as soon as possible after their withdrawal, and when the time was extended beyond twelve hours we excluded such from our table given above.

Before returning to the further consideration of our subject, there is a side problem in the discussion of acidosis as related to edema upon which the writer may be permitted to enlarge.

In all Fischer's experiments he used free acids and estimated their reaction upon the swelling of colloids (pure fibrin, for example). F. C. Goodridge and William J. Gies have taken exception to Fischer's assertion that an abnormal production or accumulation of acid in the tissues of the body plays an important, if not the chief, role in the production of edema. Fischer answers the criticism of Goodridge and Gies by showing that these authors base their criticism on false premises because of the fact that fibrin threads which they suspended in such colloidal solutions as gelatin, peptone solution, egg-white, blood, milk and meat juice do not swell visibly on the addition of acid to these solutions until this is added up to the point where it is "free" in the solution. Fischer calls attention to the fact that when these authors add acid to the colloidal solution in which they immerse their fibrin threads, they

increase the hydration by this means—not of the fibrin thread, *but of the colloidal solution* (they give this the "edema") as they would find if they measured its viscosity. Up to a certain point (maximum hydration under the influence of the acid) the addition of the acid would therefore tend *to prevent* the fibrin from absorbing water. Only if acid got into it and free water were available could the fibrin thread be expected to swell (Martin H. Fischer).

In a personal communication Fischer writes that the experiments of Bauer are also incorrect. Bauer found a *decrease* in the swelling of the brain and spinal cord on adding an acid. Fischer, criticising these experiments, finds that Bauer worked with stale (6-24 hours old) brain and cord, and thus the acidity of this *plus* what Bauer added exceeded the optical swelling point of nervous tissue. In addition, the presence of precipitation-effects also tend toward a dehydration which Bauer failed to recognize and accord significance.

For the writer's part, he thinks Fischer's standpoint well taken, and to estimate the amount of swelling which the cerebro-spinal fluid of itself—and under the circumstances of an acidity *which was not free acidity*—could bring on he performed the following series of experiments which, although not distinctly concerning our problem, yet have an important bearing on this controversy of edema in general, and additionally is of interest in our study of cerebral edema.

Conceding the given acidity in the fluids from meningitis to be of the "combined variety," will pure fibrin (colloid) swell in it? To answer this question, an equal, measured amount of pure fibrin was placed in four specially constructed test tubes upon whose side a scale of measurement was placed so that at a glance the increase in volume of the fibrin could be read, and recorded.

In each of the four test tubes equal quantities of cerebro-spinal fluid, sodium hydroxide, hydrochloric acid, and sterile distilled water were respectively placed. Readings were taken of the increase in volume of the fibrin at stated intervals. Needless to say, the acidity of the cerebro-spinal fluid created a swelling of the fibrin, more than the fibrin swelled in distilled water, and this reaction took place in spite of the fact that the cerebro-spinal fluid was a colloid in itself and it, too, must have been in a state of increased viscosity. The results of the experiments are shown in Tables II, III and IV.

TABLE II—EXPERIMENT No. 10.

Nature of Fluid Tested	Original Volume	Height in mm. of the swollen fibrin, at designated time		
		3 Hours	6 Hours	24 Hours
Fluid=0.028944 grams HCl.....	10	20.25	20.50	20.75
n/10 HCl	10	50.00	50.00	50.00
n/10 HCl	10	50.00	50.00	50.00
Sterile, distilled water.....	10	20.00	20.50	20.50

TABLE III—EXPERIMENT No. 11.

Nature of Fluid Tested	Original Volume	Height in mm. of the swollen fibrin, at designated time		
Fluid=0.028944 grams HCl.....	10	20.50	20.75	20.75
n/10 Na OH solution.....	10	40.00	50.00	50.00
Sterile, distilled water.....	10	10.25	10.50	10.50

TABLE IV.—EXPERIMENT No. 12.

Nature of Fluid Tested	Orig'l Vol.	Height in mm. of the swollen fibrin, at designated time				
		½ hour	1 hour	1½ hrs.	72 hrs.	108 hrs.
Fluid=.0123012 gms. HCl	10	10.25	10.50	10.75	20.25	20.00
Ditto .03618 gms.....	10	10.50	20.00	20.00	20.75	20.75
n/100 Na OH Sol.....	10	20.00	20.25	20.50	20.50	20.50
Sterile, distilled water.	10	10.75	10.75	10.75	10.75	10.75
n/100 HCl Sol.....	10	10.75	20.00	20.00	20.00	20.00

From these experiments it is seen that fibrin (colloid) swells most in the cerebro-spinal fluid with the highest amount of combined acidity. The reactions are somewhat slower than when free acids are tested out, and with which we made comparisons. Furthermore, at the end of twelve hours the fibrin partly goes into solution in the tubes with the free acidity. During these experiments care must be exercised to protect against extraneous infection.

While the writer does not base any final conclusions on the experiments here detailed (subsequent work will be reported) he thinks they at least are indicative of the correctness of Fischer's contentions.

One other series of experiments must be mentioned here and detailed, because of their bearing on the question of "combined acidity" and its relation to the production of edema.

To estimate the amount of combined acidity which body tissues can produce without bacterial infection, and to estimate the amount of edema such combined acidity is capable of producing in a given interval of time, the following was done:

EXPERIMENT No. 13.

A kidney was removed from an herbivorous animal (rabbit) under sterile, aseptic precautions, and sectioned and placed in sterile test-tubes

and covered with sterile blood-serum, whose reaction previously estimated was found to be distinctly alkaline. The surface of the blood serum was covered with sterile alboline to exclude air, the tissues were left about ten days and then the reaction was taken. The reaction is now found to be neutral to litmus paper and acid to phenol-phthalein solution. The acidity equaled .094068 grams of HCl in 100 ccm. of fluid specimen. Culturally the specimen is sterile.

As in the previously given experiments with the spinal fluid, four test tubes are now filled with equal, measured amounts of pure fibrin (powdered) and to this was added respectively kidney-blood-serum, n/100 HCl., n/100 Na OH, and sterile distilled water. The details of the increase in the fibrin volume is as follows in Table V.

TABLE V.—EXPERIMENT No. 13.

FLUID TESTED	Original Volume	Height in mm. of fibrin volume at specified time.			
		½ hour	36 hrs.	44 hrs.	7 hrs.
Sterile, distilled water.....	10	10.50	10.33	10.75	20.00
n/10 HCl solution.....	10	30.00	40.00	50.25	50.00*
n/10 Na OH solution.....	10	30.00	40.00	40.25	40.50*
Fluid from autolized kidney...	10	20.00	20.25	20.25	80.00*

This experiment was repeated with similar results, although the individual details of the figures differed—on the whole, it proved what the colloidal cerebro-spinal fluid had shown, e. g., that a swelling of fibrin was obtained in accordance with the proportion of acidity present, and the reaction takes place in spite of the fact that the acidity is of the combined variety, the autolized kidney-blood-serum having previously been tested for free acidity and found to be negative. The reactions were again shown as slower in their onset than the fibrin reaction to free acidity. Available water seems a necessity.

Summarizing the evidence thus adduced, we find, that in meningitides there is presented a condition of *"combined acidity" in the cerebro-spinal fluid* which interacts on the colloids of the brain and the investing membrane and adds to the viscous cycle of events *by producing an edema of these tissues*, which edema is still further increased by the interference in the oxygenation of the central nervous system.

Returning now to the more immediate consideration of our subject, and having shown that an immediate examination—after its withdrawal from the body—of the cerebro-spinal fluid from cases of meningitides evidences an acidity which results in an edema of the brain-tissues and the tissues of the meninges, it follows that

*Fibrin was dissolved partly.

the swelling of these tissues necessarily must present obstacles to the circulation of the cerebro-spinal fluid.

The meningeal tissues include the Pacchionian bodies, which act as the entrance-gate for the fluid from the subdural and subarachnoidal space into the venous blood system. In the child these bodies are not present during the period of life when the fontanelles are open. When these close, and the *"give of the scalp"* is removed by the deposit of bone closing the cranial sutures and the fontanelles, then these spongy villi are developed, and expand and contract with the heart and respiratory rhythm as a sort of "break-pump," regulating the flow of the fluid from the cranial spaces into the lacunae and blood sinuses. In the child their absence is significant during the period when the skull itself is yielding to the pulsations caused by the heart-beat and respiratory rhythm. So far as the writer is aware, no one has heretofore explained this significant feature of the Pacchionian bodies and the function they perform, and the explanation of the substitute for their absence in the infant.

A change in the consistency (thickening) of the delicate membranes of the Pacchionian bodies conceivably acts as a hindrance to the passage through these membranes of the fluid, just as the *wheal* following an insect bite, producing a local edema, prevents blood from getting into the infected area for a time. Microscopical examination of these bodies, taken from a case of purulent meningitis—of traumatic origin—examined by the writer, demonstrated an increase in the swelling of the fibers of the connective-tissue elements, plus a round-cell infiltrate, besides a swelling and granulation of the cell-elements; thus substantially giving the physical evidence of the edema of the Pacchionian bodies. From the experimental work in the previous section of this article, the amount of disturbed functional activity which may result from a simple stasis of the cerebro-spinal fluid is shown to be considerable. How much more pronounced, therefore, will the symptoms from the compression of the blood-supply to the brain substance appear when not only the acidosis of this organ, but also an accumulation of the cerebro-spinal fluid takes place to add its vicious quota to the factors already present in the compression elements in meningitides.

Furthermore, it has already been shown that in anemia of the brain an increase in the amount of cerebro-spinal fluid is demonstrable, and from the observation of Araki and Zillensen we learn

that the production of lactic acid occurs in animals, no matter *how* the lack of oxygen is produced. One might enlarge further on this theme of lactic acid formation in the tissues under the influence of lack of oxygenation—or under conditions of stress of excessive function, as in forced work, athletics, etc.—states of affairs in which metabolic products are produced faster than their removal —but the physiological and bio-chemical text-books give all this data and those interested are referred to the works of Aberhalden, Hammersten, and Halliburton for this information. The writer will have occasion below, when discussing the significance of his chemical findings in cases of meningitides, to briefly detail some of the observations extant on lactic acid formation. Here he will only give the results of examinations made on spinal fluids to show that lactic acid was demonstrated in the fluids from meningitides. The relationship of the acidity of the fluids, and the relative amounts of lactic acid found in the varying degrees of meningeal symptoms, must, for the present, remain unanswered, as the data presents factors requiring further inquiry, on the results of which reports will be subsequently made. For the present no conclusions are drawn, except to say that the acid was found and to give an approximate estimation of its amount in the given case.

The writer modified the Uffelmann reagent to give an approximate chemical estimation of the amount of the lactic acid present in the given specimen. The method employed consisted in the following: Standardize the Uffelmann reagent as follows: 5 per cent ferric-chloride solution, 1 part; 1 per cent carbolic acid solution, 5 parts. Mix these.

To this solution, thus standardized, the cerebro-spinal fluid is added drop by drop from a small pipette, and the first tinge of a yellowish color observed, as the drop enters the reagent is noted. A fluid which, upon the addition of *one* drop, shows the yellow color in the reagent is marked +1; if two drops are required to produce the reaction it is marked +2, three drops +3, etc., etc.

Reactions occurring with one drop up to three drops of fluid are designated *"marked amount";* when it requires from four to six drops to produce the reaction they are designated *"moderate in amount,"* and when from six to ten drops, or more, of fluid is required to produce the reaction it is designated as a *"trace," "faint trace,"* etc. In this way a rapid approximate quantitative estimation is possible.

In the following—Table VI—is given the results of our analysis of thirty-four fluids for the presence of optically active lactic acid.

TABLE VI.—LACTIC ACID ESTIMATION OF 34 CEREBRO-SPINAL FLUIDS.

No.	Diagnosis	Drops Required	Designates
41	Anterior poliomyelitis	0	None
42	Meningococcus meningitis	0	None
45	Anterior poliomyelitis	0	None
46	Tuberculous meningitis	+2	Marked
47	Tuberculous meningitis	+2	Marked
48	Tumor (T. b. c.) cerebellum	+5	Moderate
49	Cerebro-spinal rhinorrhea*	+5	Moderate
50a	Cerebral embolism	+1	Marked
50b	Cerebral embolism	+2	Marked
50c	Cerebral embolism	+2	Marked
51a	Tuberculous meningitis	+3	Marked
52	Meningococcic meningitis	+3	Marked
54	Purulent (otitic) meningitis	+5	Moderate
55	Anterior poliomyelitis	+1	Marked
56	Amaurotic family idiocy	+1	Marked
57	Purulent (otitic) meningitis	+2	Marked
58	Cerebral embolism**	+9	Trace
59	Tuberculous meningitis	+8	Trace
60	Tuberculous meningitis (staring picture)	+2	Marked
61	Chronic hydrocephalus	+9	Trace
62	Chronic hydrocephalus	+10	Trace
63	Meningism†	+10	Trace
64	Otitic—post-operative sepsis	+5	Moderate
65a	Meningococcic meningitis	+2	Marked
66	Meningism†	+10	Trace
67	Meningococcic meningitis††	+8	Trace
68	Tuberculous meningitis	+5	Moderate
69	Tuberculous meningitis	+2	Marked
70	Meningococcic meningitis	+2	Marked
71	Meningococcic meningitis	+1	Marked
72	Chronic hydrocephalus	+14	Trace
73	Purulent (otitic) meningitis‡	+1	Marked
74	Meningism, accompanying scarlet fever	+6	Trace
75	Tuberculous meningitis	+8	Trace

The evidence thus far produced shows that the predominance of the pressure-symptoms as found in meningitides is, in a large measure, due to a state of edema of the cerebral and meningeal tissues. This edema is the result of an acidosis, evidenced clinically by the varying degree of acidity found in the cerebro-spinal fluid obtained through lumbar puncture, and although no attempt is made at this time to co-relate the degree of pressure symptoms to

*Patient bedridden with acute attack of rheumatism at time fluid was taken.

**Same case as 50a, 50b, 50c,—now meningeal symptoms have abated.

†Meningeal symptoms, which rapidly and spontaneously disappeared. No signs of meningitis.

††Fluid obtained during end of second week when recovery apparent. sensorium almost clear.

‡Fulminating type,—death in two days from onset.

the degree of acidity found, yet the latter seems to bear a definite relationship to the former, and, finally, in the cases which clinically present the more stormy picture of disturbances of the sensorium, larger amounts of lactic acid are demonstrable in the spinal fluid.

IV.

In the preceding section we were mostly concerned with a study of the factors producing pressure symptoms, and their underlying physico-chemical causes. It is now desirable to take up another aspect of the symptom-complex and discuss this second aspect of our problem in terms of factors common to all meningitides.

The casual relationship of pathogenic micro-organisms to meningitides has long been established, and the result of the vast amount of labor expended in isolating and recognizing these pathognomonic bacteria is accepted here without question. A rich and growing literature attests the work performed, and those interested in this aspect of meningitis are referred to special works on the bacteriology of this disease. Good resumés are to be found in the monographs of Hasslauer, Kopetzky, Elser and Huntoon, of these micro-organisms, their method of isolation, cultural characteristics, as well as their diagnostic significance when demonstrable in the cerebro-spinal fluid.

For the consideration of the questions we are about to present the mere presence of pathogenic micro-organisms in the fluid from the central nervous system is of smaller moment—excepting their demonstration as a diagnostic aid—than the realization that the disease we are endeavoring to study is a succession of changes in the tissues, generally resulting from the growth within them of pathogenic microbes. In other words, the fact of importance to us here is the recognition that meningitis is the picture of an interaction between the tissues of the central nervous system and the micro-organisms, and it is this interaction which in part produces the additional elements of our clinical picture. This inter-action results in a destruction of tissue cells on the one hand, and the production of *toxins* and *ptomaine* on the other hand, and it is the recognition of these two factors which concern us mostly in this section.

To render comprehension of our argument easier, we again present the conclusions arrived at first, and then the facts at hand which are found to substantiate this conclusion.

The result of pathogenic bacterial growth in the central nervous system is evidenced by the EARLY *disappearance of the carbohydrate element in the cerebro-spinal fluid, and the presence in its place of nitrogenous products, the result of tissue destruction. These two factors, particularly the latter, produce those symptoms of general intoxication which, in addition to the pressure symptoms, make up the clinical picture of meningitis.*

Before proceeding directly to the subject-matter of this section a few general considerations relative to the activity of bacteria in the tissues are in order.

The products manufactured by micro-organisms vary. Among the substances produced in the decomposition of animal tissues, more particularly from what we call putrefactive action of bacteria, are a class of chemical bodies of a basic nature. To this class belong the alkaloidal group we term *ptomaines* (Selmi, Brieger, and Gautier). Certain of these are poisonous, designated as *toxins*. These same substances, in addition to those produced as products of decomposition of protein elements of the tissues (but not necessarily of bacterial origin) as the result of metabolic tissue changes, and termed by Gautier *leucomaines*, are accumulated in the cerebro-spinal fluid and produce their poisonous effect not only on the cells of the brain tissue, but, by their dissemination through the blood into which they are carried by the cerebro-spinal fluid, they affect the whole body. These effects are to be found in the state of nervousness, depression, photophobia, sleeplessness, hallucinations, active delirium, prostration and even coma. Such symptoms correspond with nervous disturbances set up by other toxic agents, and can be reproduced experimentally by the intravenous injection of the sterile culture-fluids of bacteria, or products of growth of specific microbes (Adami).

Furthermore, there is evidence that bacterial toxins are capable of acting directly upon the nervous system. Examples of this are found in the recent work of Flexner and Lewis, of Landsteiner and of Popper, in connection with the virus of anterior poliomyelitis; and the findings of Rainy of a direct histologically demonstrable change in the cells of the spinal cord in diphtheria; while the older work of Ransom and Archibald in regard to the effects of tetanus toxin, and that of Di Vestea and Zagari in regard to rabies are also examples in point.

The activity of bacteria is of two kinds, designated *fermentative* and *putrefactive*. Both these terms are generic, indicating micro-

bic activity upon two distinct types of organic compounds, namely, the carbo-hydrates (and related compounds) and the nitrogenous bodies. Many bacteria are capable of both kinds of activity (Kuhn, Kendall, and others).

Kendall draws attention to two distinct processes occurring in every fermentation by bacterial activity, viz.:

1. Destruction of carbo-hydrates, containing no nitrogen, and

2. The metabolism of nitrogenous substances which all micro-organisms need in their dietary.

In putrefaction the protein elements are destroyed, and Kendall finds it very difficult to distinguish between the widespread breakdown of protein, the essential factor of the process, and the very limited utilization of protein by the bacteria for purely dietary purposes. Further, as this observer points out, in the last analysis, both fermentation and putrefaction are enzyme phenomena, differing slightly only from the digestive processes in man.

The above terms—fermentative and putrefactive bacterial activity—are to be limited to the specific action of micro-organisms, or enzymes, elaborated by them. Together these terms represent the most fundamental phenomena of bacterial metabolism (Kendall).

From the work of Lyons and Cramer, Drytus, Nashimura, Duclaux, Nagle and others, it is shown that bacteria vary in qualitative composition, and elaborate differing compounds, depending upon the composition of the media in which they are grown. Kendall concludes that there is little doubt that the bacteria is directly influenced by the presence or absence of utilizable carbo-hydrates. Further, from the observations of Bienstock, Kuhn, Charrin, Bouchard, Woodhead, Wood, and others, this predeliction for the sugars creates a certain antagonism between the bacteria.

The metabolism of those bacteria which destroy carbo-hydrates is such that it does not produce harmful effects on the tissues so long as there is available carbo-hydrate, whilst those bacteria whose metablosm requires protein create toxins (products of the NH_3 caminen-alkaloid-ptomaine group). Further evidence along these lines is presented by the classical work of Theobald Smith in his observations on diphtheria bacillus and its production of toxins. who found that the toxins were produced only in the absence of sugars from the culture media. He found the presence of even small amounts of dextrose prevented the diphtheria bacillus from attacking protein. And so examples might be multiplied.* In a

*Full bibliographies and experimental details on these and similar observations are found in Kendall, and Kuhn's works to which the reader is referred.

subsequent communication the writer hopes to develop the special bearing these findings have on another aspect of the problem of meningitis. This part of the work is unfinished, as yet, and it suffices for our present purposes to accept the generalization of Kendall and others, and from it formulate a general law to the effect *that the toxicity of the bacterial infection is dependent on the protein destruction which accompanies it,* and to the disappearance of available carbo-hydrate from the media in which the microbes are propagated. In passing it is to be remarked that there are bacteria which specifically have a predeliction for the nitrogenous elements in the media of growth, yet in its applicability the above-stated general law holds good nevertheless.

Returning now to the more immediate consideration of our subject, attention is directed to the presence in the normal cerebro-spinal fluid of a carbo-hydrate, which for a long time has been the subject of controversy and investigation.

According to Halliburton, the normal fluid contains a substance in it which reduces the copper of Fehling's solution. For some unknown reason this substance does not readily give the fermentation test with yeast. It was thought, therefore, for a long time that it could not be a sugar. Halliburton believed it, at first, to be an arometic body allied to pyrocatechin. V. Jaksch thought it to be isomaltose. Nowratski, however, demonstrated it to be a dextrose, a conclusion which Halliburton accepts, and Hammersten and all others now generally believe.

Most authorities have utilized the reduction of Fehling's solution to demonstrate its presence, and in the examinations which are herewith recorded the writer at first used the Fehling solution as a control, but in the later examinations almost exclusively used the Benedict reagent, as hereafter described.

Having obtained, through the courtesy of Dr. M. D. Kaplan, of the Neurological Institute, New York City, specimens of normal fluid,* and having under observation a case of cerebro-spinal rhinorrhea, in addition to withdrawing normal fluid from a patient to relieve an intense tinnitus the writer was in a position to determine the presence of a copper-reducing body in all the normal fluids examined. V. Jaksch places the amount of this body at from .06

*Fluids drawn from patients for diagnostic purposes in diseases other than acute pyogenic meningeal infection, for Wasserman reactions, etc., and found to contain no bacterial flora, nor any cellular elements.

to .08 per cent in an average of twenty specimens examined, titrating against a standardized Fehling's solution. The writer's figures do not place the presence of this carbo-hydrate so high, finding it between .02 to .04 per cent in eight examinations made. The writer believes the amount varies as the needs of the central nervous system for this carbo-hydrate require, and hence the differing findings from quantitative analysis.

For the purpose of my analysis the reagent recently published by Dr. Stanley R. Benedict, of Columbia University, was employed. His reagent* is a very delicate one, much more specific than the Fehling's solution, in that it is not reduced by many non-carbo-hydrate substances which readily enough reduce copper in the presence of strong alkali.

The presence of a dextrose in the normal cerebro-spinal fluid being thus established as a physiological fact, and bearing in mind the arguments presented above regarding the predelection of most bacteria for carbo-hydrate diet where such is available, we are not surprised to find that with the *onset* of acute bacterial infection of the cerebro-spinal fluid and the central nervous system, that the examination of the fluid so withdrawn by lumbar puncture shows *an absence of this copper-reducing substance*. The absence of this copper-reducing substance in acute infection of the meninges has been demonstrated by Andrew Connell, M. D. Kaplan and others. Its significance as one of the earliest diagnostic factors has, however, not received the recognition which it should, especially where differential diagnosis between meningeal symptoms—meningisms—and true meningitic inflammation is sought.

Furthermore, as far as the writer is aware, no one has heretofore offered even a plausible explanation of its disappearance in the acute bacterial infections of the meninges.

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*BENEDICT REAGENT FOR QUANTITATIVE ANALYSIS:

Copper sulphate (pure crystals)	18. ccm.
Sodium carbonate (crystalized)	200. ccm.
Sodium or potass. citrate,	200. ccm.
Potass. sulphocyanate,	125. ccm.
5% solution potass. ferro-cyanid.	5. ccm.
Distilled water to make total volume	1,000. ccm.

With the aid of heat, dissolve the carbonate, citrate and sulpho-cynate in about 800 ccm. water, filter. Dissolve the copper sulphate separately in 100 ccm. water and pour solution slowly into the other liquid with constant stirring. Add the ferro-cyanide solution, cool, and dilute to exactly one litre. The copper salt only need be exactly weighed. 25 ccm. of this reagent are reduced by 50 mg. of carbohydrate (glucose, dextrose, etc.)

BENEDICT REAGENT FOR QUALITATIVE ANALYSIS:

Copper sulphate (pure crystals)	17.3 gm. or ccm.
Sodium or potass. citrate	173.0 gm. or ccm.
Sodium carbonate (crystals)	200.0 gm. or ccm.
Distilled water to make	1,000.0 gm. or ccm.

The copper sulphate should be separately dissolved and added to the solution of the mixture of the other ingredients.

From the observation of a thousand cases, and examinations to determine the presence or absence of this copper-reducing body in meningitis Connell reaches the following conclusions: That it is always absent in the acute infections; that it reappears as the bacterial organisms disappear from the fluid, and, with the exception of tuberculous meningitis, its reappearance in subsequent examinations of the fluid affords the readiest means of ascertaining the progress of the disease. In tuberculous meningitis, unless the onset is very acute, the writer does not consider it a reliable test—a conclusion which Connell's observations substantiate.

That the presence of this carbo-hydrate body remains unaffected in mental states which are not the result of acute bacterial causation, the observations of Cavazzini, Schaefer, Zdarek, and Panser demonstrate. The writer found it present in the following conditions, all of which were accompanied with meningeal symptoms:

TABLE VII—COPPER REDUCTION WAS PRESENT.

Disease.	Number of Cases Examined.	
Eclampsia	1.	
Delirium tremens	2.	
Concussion of brain	1.	
Chronic tuberculous meningitis	5.	
Anterior poliomyelitis	4.	
Tubercle of cerebellum	1.	
Cerebral embolism	3.	(In different examinations of same patient.)
**Meningococcic meningitis	2.	
Meningism	4.	
Hydrocephalus	3.	
Otitic sepsis	1.	
	29	examinations.

In regard to the above table (VII) two facts are called to mind: In tuberculous meningitis, only in those cases where the onset was gradual and the clinical picture unfolded slowly was the copper-reducing body found—in those cases with sudden onset and a stormy clinical picture this body was absent. In the late stages of meningococcic meningitis, when the patient's recovery was apparently assured, the reduction of the copper was also found. As the next table (VIII) will show, in all other cases of meningitis the copper reduction was absent.

In the following table (VIII) are the results of our examinations in which the copper reduction was absent. All were acute microbic infections. At this time it may not be amiss to add that *the examinations in showing absence of the copper reduction were*

**Late in the disease when recovery was on hand.

usually obtained long before the bacterial, cultural or smear preparations gave information of diagnostic value.

TABLE VIII—COPPER REDUCTION WAS ABSENT.

Diseases.	Number Examined.
Purulent (otitic) meningitis	5 cases.
Meningococcic meningitis	4 cases.
Acute tuberculous meningitis	4 cases.
	13 cases examined.

From all that precedes we conclude that the evidence seems to justify the belief that *there is always present in the cerebro-spinal fluid a carbo-hydrate which at the onset of bacterial infection is utilized by the microbes as a food, and that it disappears from the spinal fluid early in the disease, to reappear later simultaneously with a falling off in the numbers, or with the disappearance of the micro-organisms presented by the case.*

Finally, *in this reaction*—the estimation of the presence of the carbo-hydrate body in the spinal fluid, and the determination of its absence—*we have one of the earliest and most reliable signs of meningitis*, and *later* a *reliable test* to afford information as to the *progression* or *retrogression* of the *infection of the meninges.*

V.

We have now to discuss certain bio-chemical changes in the cellular elements of the central nervous system, which have an important bearing on the problem presented in meningitides. We will endeavor to deal with these changes, produced by microbic and intra-vitem enzymotic activity which results in the formation of new chemical bodies, and identify their origin and trace their destiny from the cellular structure of the central nervous system to their disappearance. We will further endeavor to show the poisonous character of these new compounds, which circulate through the central nervous system, and add their quota to the toxins produced by microbic activity in the causing of the "poison-effects"—or toxic symptoms—observed in the clinical picture.

To render our argument clear, we will at once state the general conclusion and then proceed with the presentation of the facts upon which it is based.

In the evolution of meningitis, the stasis—or the interference with the normal circulation of the cerebro-spinal fluid—causes an accumulation of the products of bacterial and enzymotic activity

to take place in the fluid. The bodies thus collected are nerve poisons and produce their deleterious effects directly on the cells of the central nervous system—evidence of which is seen in the clinical picture. The products of cellular degeneration thus formed and collected are recognized as "penultimate" products of disintegration of the protein constituent of the brain matter.

In presenting the evidence upon which this general conclusion is based, it is of moment to glance at our knowledge of metabolism of the central nervous system, as a means of affording a slight insight into the questions involved in this discussion.

The metabolism of the central nervous system, both as a whole and in its various component parts, has not been worked out heretofore with any degree of satisfactory results. As Halliburton points out, we are so accustomed to associate the word metabolism with the activity of the protein constituent of protoplasm that we are sometimes apt to forget that other material frequently exhibits a similar alternate or simultaneous series of anabolic and katabolic phases. This statement is particularly pregnant regarding the complex phosphorized molecule which constitutes the chief element in the tissue we are studying. Further, it might be assumed that an idea of the metabolism of the nervous tissues was obtainable by a search for and an identification of end-products, but, although this goal is partly in view, the trouble seems to lie in the extremely faulty and imperfect state of our fundamental knowledge of the composition of nervous tissues.

We have knowledge from the works of Gumprecht, Breiger, and others, that a large part of the nervous tissue of man consists in the so-called myelin substances, among which *lecithin* is the best known prototype. A brief survey of the decomposition products of lecithin is therefore important in studying the degenerative products from cell bioplasm of brain tissue in meningitis.

Lecithin breaks up through degeneration of nerve tissue into its component parts, i. e., into *cholin* and a glycerin phosphoric acid in which the fatty acid radical is kept intact. Later in this paper we shall have occasion to deal with the evidence presented in meningitis of further advance of the disintegration process of lechithin, for this disintegration results in the formation of a glycerin, *a neutral fat,* and phosphorus. Now, it suffices to say that the writer found this advanced degenerative process shown, in fatal cases of meningitides, by the presence in the cerebro-spinal fluid of

higher percentages of a neutral fat than were observed in the fluid in the earlier stages of the disease, or in fluids from diseases other than meningitides.

Glancing at the reduction, or degenerative processes of lecithin in the laboratory, it is found that lecithin, on decomposition with baryta-water, with alkalies and acids, yields fatty acid, glycero-phosphoric acid, and cholin. The cholin is also obtainable when lecithin, under activity of enzymes, is broken up, splitting off with a fatty acid. Under the so-called putrefactive activity of bacteria, lecithin yields glycero-phosphoric acid and cholin. The ultimate decomposition products result in the formation of methylamin, ammonia, carbon dioxid and marsh-gas (Hasebroeck).

From this it is seen that even in the laboratory the cholin and the phosphorized fats are not the *ultimate* decomposition products, but represent rather the *penultimate* bodies produced. As we shall have occasion later to trace these bodies in the human system, the parallelism between the laboratory findings and the metabolic processes in the system will be shown. Here, it suffices to study the cleavage product—cholin—more particularly.

Cholin is a poisonous base which, under the action of bacteria, is changeable into another base still more poisonous termed *neurin* (according to the findings of Brieger). The effects of cholin on the central nervous system has been studied by both Halliburton and Donath. The latter experimentally produced tonic and clonic cramps which lead to paralysis by injecting cholin sub-durally over the motor area. Donath's conclusions substantiate fully the observation that cholin is a severe nerve poison. Both cholin and neurin are alkaloidal substances closely related to others—namely, betain, the slightly poisonous alkaloid of the common beet, and muscarin, the highly poisonous alkaloid of the toad-stool.

The writer permitted fresh rabbit brains to undergo autolysis for some hours and cholin was found in abundant quantity, more so than was obtainable after macerating fresh brain without autolysis. Cholin has been extracted from brain tissue of various animals and from the human subject by a number of investigators.

In both the cerebro-spinal fluid and also in the blood of dogs upon which cerebral anemia had been produced (see section II for details of experiments), increased quantity of cholin was demonstrable over the quantity found in relative proportion to the smaller amounts of cerebro-spinal fluid obtained from the control dog.

Our analysis of blood from the control dog was negative as to the finding of cholin. The explanation of these findings is based on the following:

It is first to be noted that the most active part of the nervous system, the grey matter, yields most cholin to solvents (Halliburton). It is recalled that the nervous centers in the brain are richly supplied with blood-vessels which furnish them abundant nutrient material to maintain their normal metabolism. Halliburton and others have shown that cerebral anemias rapidly produce pathological changes in nerve cells and the destruction or decomposition of the cell bioplasm quickly supervenes. In nerves this has been particularly well shown, and the further observations of Verworn, Baeger, and Froehlich (cited by Halliburton) of the necessity for the presence of oxygen in the maintenance of cell-life in nervous tissue is equally significant, while the statement of Halliburton and many others that nervous tissues become *acid* when they die, is also of moment. In our experimentally induced cerebral anemia all these factors are present—the lack of oxygenation and other nutrient material necessary to cell-life; the presence of acidity in the spinal fluid; the brain tissue edema, with its accompanying acidosis—these factors have all been demonstrated to be prime factors. Therefore, we are enabled logically to account for the presence of this product in our experimentally induced cerebral anemia, and, from what has gone heretofore, also in the cases of meningitides.

Gumprecht, Gulewitch, Halliburton, and others, have demonstrated that in perfectly normal cerebro-spinal fluids there exists minimal traces of cholin. This trace of cholin Halliburton regards as representing a small balance on the wrong side of the account —as evidence of katabolism of the brain tissue. Traces of cholin have also been demonstrated in the blood by Zuco, Gumprecht, and others. It has been sought in the urine of animals, after injection, but has not been detected—investigations along this line having been undertaken by Donath, Mott and Halliburton. Only Gumprecht was enabled to find cholin in the urine of his animals after he had injected into them very large quantities of it.

As in the laboratory work lecithin decomposition at first yields cholin, and its ultimate decomposition destroys this basic substance —producing the ammonia, marsh-gas group of compounds—so in the chemistry of the body the immediate destruction of nerve tis-

sue produces cholin, which is thrown into the cerebro-spinal fluid, carried with the fluid into the venous blood, and somewhere in the blood, before its metabolism-products are excreted by the kidneys. ultimate decomposition takes place and cholin is not found in the urine. We are, therefore, justified in concluding that cholin is a *penultimate* product of brain tissue metabolism.

Cholin has been found in the cerebro-spinal fluid in many nervous diseases, and to a somewhat lesser degree it has also been found in such patients' blood. Thus, Gumprecht finds it in typhoid fever; Huntington's chorea—with impaired intellect; and in the meningism, or meningeal symptoms of scarlet fever. He found it most abundant in cases of meningitis. Mott and Halliburton report it as present in appreciable quantities in both the blood and cerebro-spinal fluid from cases of progressive paralysis, sclerosis—combined and disseminated types—alcoholic polyneuritis, Beri-Beri, etc. Donath and Hastings found it in cases of alcoholic psychoses, while Gruenbaum observed it in paralysis agitans, transverse myelitis, and, in small amounts, in herpes zoster—and finally, J. P. Atkinson and C. B. Fitzpatrick, of the New York Health Department, report finding cholin in cases of rabies. Halliburton's findings of cholin in degenerative nervous diseases is another classical example.

The examinations undertaken by the writer fully substantiated the findings of Halliburton, Mott and Donath. As the following table (IX) shows, the sharpest reactions for cholin were presented in cases of meningitides, and no difference was observable in the tests made on cases of epidemic cerebro-spinal meningitis, or otitic purulent meningitis. Smaller quantities were demonstrable in the cases whose clinical picture gave evidence of a less systemic toxic infection, although this is not to be understood as a claim to having established any co-relation between the clinical picture and the quantity of cholin approximately thought to be present in the given case. In the first place, the material studied was too meager to draw definite conclusions, and in the second place quantitative tests for cholin have not been satisfactorily perfected. For the present, therefore, we leave this question open. Finally, it is to be remarked that cases other than meningitis, which presented meningeal symptoms—irritative and poisonous effects—also presented the finding of cholin in amounts increased over what we are arbitrarily pleased to term the normal, minimal trace.

TABLE IX—DETERMINATION OF PRESENCE OF CHOLIN

Diagnosis of Condition	Number Examined	Cholin found present in		
		Abundance	Moderate Amount	Normal Trace
Meningococcus meningitis	6	2	3	..
Tuberculous meningitis	5	4	1	..
Purulent (otitic) meningitis	3	3	..	..
Meningism	1	..	..	1
Cerebrospinal rhinorrhea	1	..	..	1
Anterior poliomyelitis	2	1	1	..
Anterior poliomyelitis (late)	1	..	..	1
Cerebellar (T. b. c.) tumor	1	..	..	1
Cerebral embolism	4	..	1	3
Amaurotic family idiocy	1	..	..	1
Totals	24	10	6	8

In testing for this body in the cerebro-spinal fluid, the writer used the following technic, the results being much easier determined than by any of the other methods which physiological-chemistical text-books give. In most instances both tests were employed, especially in the earlier work, so as to have the one test check up the other. In later examinations the crystals were not resorted to, it being satisfactorily shown that the precipitation test was reliable.

About 10-15 ccm. of the cerebro-spinal fluid to be examined for cholin is vigorously shaken with an equal amount of *absolute* alcohol. This is now put into a porcelain dish and placed on a water bath and slowly evaporated to dryness. The residue is then carefully collected, and some of it placed on a clean microscopic glass slide. To this residue there is now added Rosenheim's iodo-potassium iodid solution.* In a short time dark brown plates and prisms of *cholin-periodid* begin to form and are observable under the microscope. These crystals somewhat resemble typical crystals of hemin. If the fluid be permitted to stand, thus allowing the moisture to evaporate, the crystals finally disappear and in their place are found dark brown oily spots. Upon the addition of fresh iodin solution the crystals reappear (Hawk). V. Stenek's observations substantiate this test.

The difficulty in identifying crystals makes this test an unsatisfactory one considered for practical purposes. The writer used it mostly as a check to the test which is next described. The latter is better suited for practical work, as according to whether the precipitate is found slight, moderate or heavy in amount so a rough

*Rosenheim's iodo-potassium iodin solution is prepared by dissolving two grams of iodin and six grams of potassium iodid in 100 ccm. of water.

approximation is obtainable of the amount of cholin present in the quantity of fluid examined.

Again, taking from 10-15 ccm. of cerebro-spinal fluid, and shaking it vigorously with *absolute* alcohol, in equal amounts, it is placed in the evaporating dish over a slow flame and brought to dryness. The residue is again extracted with absolute alcohol, insoluble particles filtered out, and the alcoholic extract again evaporated to dryness. The process of extraction and evaporation is repeated several times to remove all trace of potassium or sodium salts, which tend to cloud the end reaction. The final residue is dissolved in 2-3 ccm. of distilled water, and then there is added to the solution, which is now put in a test tube—*one drop* of Kraut's reagent.* Cholin is indicated by a bright brick-red precipitate (Hawk).

The writer tried the various platinic chlorid tests and found his results substantiated, but thinks the above tests better adaped for routine work.

When the cholin was thus found it was, as far as possible, further identified by various special tests. These tests are to be found in the books of Hammersten, and others, on physiological chemistry.

From the foregoing we are justified in assuming that the normal metabolism of the cells of the central nervous system results in throwing into the cerebro-spinal fluid stream minimal traces of lecithin decomposition-products—namely, cholin (and other products)—the cerebro-spinal fluid carries these into the blood where further decomposition ensues. Under the influence of bacterial poisons, and the other factors which we have shown are common factors in meningitides—the cerebral anemia, the edema of the tissues with its accompanying acidity, etc., the interference with the free circulation of the cerebro-spinal fluid—*an accumulation* of these poisonous basic products takes place, and they exert their deleterious activity on the nervous tissues directly, still further damaging them. The result of all this is seen in the evidence of toxicity of the given case, as shown in the clinical picture. Nor must we be surprised when no permanent cellular damage is shown in the cases which recover, because of the fact that with the re-es-

*Kraut's reagent is made as follows:—Dissolve 272 grams of potassium iodid in water and add 80 grams of bismuth subnitrate dissolved in 200 grams of nitric acid (sp. gr. 1.18). Permit the potassium nitrate to crystallize out, then filter it off and then filtrate up to one liter with water.

tablishment of normal conditions in the arterial supply, and in the circulation of the fluid, the poisonous bodies are quickly removed. In meningitides it is an accumulation effect, rather than a large amount of destruction presented, that is the factor; while in non-meningitic diseases, as in the general paralysis of the insane, a larger amount of cellular destruction is the cause of the abundant quantity of cholin found. From the standpoint of the chemical examination of the fluid, however, the results are similar whether we are dealing with an accumulation of cholin from a small amount of destroyed tissue elements, or whether we are dealing with larger, grosser lesions which throw into the fluid relatively greater quantities of cholin without having any accumulation effect produced because the mechanics of its removal is not concerned in this instance. This is but an added observation to those already given of the effects produced by a stasis of the circulation of the cerebrospinal fluid in meningitides.

We have seen in the study of the decomposition of lecithin that the *penultimate* products were found to be cholin, and a glycerin phosphoric acid, with an intact fatty acid radical. We have further commented on the finding that in the ultimate decomposition products of lecithin disintegration glycerin, phosphorus, and *a neutral fat* are found.

In the histological study of nerve degeneration the existence of a fatty degeneration has long been established by a host of investigators, and the re-detailing of these numerous findings would be beyond the scope of our argument. In the examination referred to, the fat droplets are striking objects, but as a matter of fact—shown by the recent work of Rosenfeld and others—the tissues are really poorer than richer in fats under these conditions (Moore). For example: Rosenfeld has shown that in a patch of yellow softening of the brain in the region of the cuneus the yield in fat =6.17 per cent, while the normal cuneus gave 8.81 per cent. According to Moore (in Hill's "Recent Advances in Physiology") nerve-degeneration is the only authentic example of a protein containing substance yielding fat on decomposition. Had the laboratory analogy of the decomposition of lecithin been accorded proper significance, this example would have found ready explanation before this. Noll, holding the fatty acid as an evidence of further (ultimate) decomposition of lecithin, with glycerin and a neutral

fat as products of the process, believes the fat deposited at the seat of the disease (degeneration), while the cholin and the phosphorus (in organic combination) are washed away.

Since the evidence adduced from the finding in the cerebro-spinal fluid of the penultimate products of lecithin decomposition have been so fruitful, it occurred to the writer to search in the fluid for the existence of products of ultimate decomposition of lecithin because of the peculiar anatomical and physiological part played by the cerebro-spinal fluid,—on the one hand its intimate connection with the nervous tissues involved and on the other its role as the carrier of metabolic products of nervous tissue metabolism from the central nervous system to the venous blood-streams for ultimate elimination.

So far as the writer is aware, no previous attempts have been made to estimate the percentage of neutral fats present in the cerebro-spinal fluid in diseases presenting meningeal symptoms, nor has the significance of the finding of such fats in connection with the lecithin decomposition of the brain tissue cells received attention.

The problem was to find a practical method for application to clinical material, in which results could be announced within a few hours.

Ether extraction and subsequent exact estimation are long, tedious procedures, but these were undertaken to check up the results as obtained, by the method outlined below. It was found that the differences were so small as to be negligible. The method finally elaborated consists in a series of procedures, similar to the Laffman-Bean modification of the Babcock method of estimating the fats of milk, the smallest obtainable Laffman-Bean flasks being used. In the first series of analyses, as stated above, the ether extraction method was employed in addition and found, for practical purposes, to coincide in results with the findings from the readings of the scale on the Laffman-Bean flasks. The writer does not want to be understood as giving the percentages of neutral fats found as *absolute, exact percentages*, but, rather like the Naguchi method for estimations of excess of globulin, etc., he desires to call attention to a method of rapid estimation of the relative amount of neutral fat presented in a given specimen of fluid, and to call attention to some clinical evidence which accompanied the finding of increased quantities of neutral fat in the cerebro-spinal fluid. The method of procedure is as follows:

1. Prepare fresh solution of equal parts of amyl alcohol and hydrochloric acid (c. p.)

2. Prepare fresh solution of equal parts of sulphuric acid (c. p.) (sp. gr. 1804) and distilled water.

3. Have ready a medium-sized beaker partly filled with cracked ice and water, to cool solutions.

4. Using a specially designed pipette graduated and marked to hold exactly 2.92 ccm., place that amount of cerebro-spinal fluid in bottom of small Laffman-Bean centrifuge flask. Place centrifuge flask in beaker of cracked ice and water to chill the fluid.

5. Now draw into the same pipette 2.92 ccm. of sulphuric acid (c. p.) and carefully empty it into the centrifuge flask, keeping the latter all the time under the iced-water to prevent charring by the acid.

6. In another pipette take up 0.6 of one ccm. of the amyl alcohol and hydrochloric acid solution, previously prepared, and pass it carefully into the centrifuge flask.

7. Now add, of the sulphuric acid and water solution, a quantity sufficient to fill the centrifuge flask to the upper level of the scale scratched in the neck of the flask.

8. Mix the solutions in the flask, keeping it in the iced-water during the procedure.

9. Place the centrifuge flask in its metallic container and place in centrifuge and twirl for five minutes at the rate of 3,000 revolutions per minute.

10. Fat, if present, will be evidenced by a highly refracting, clear solution at the top of the mixture, the upper level of which generally turns brown from exposure to the air after a short time.

11. Reading scale;—each subdivision represents .3 per cent of fat. Thus, if the fat covers 3 lines it equals .9 per cent, 8 lines equals 2.4 per cent, etc.

12. If in doubt as to the presence of fat, use a capillary pipette, draw off the upper level of fluid and place on brown fat-testing paper or, better still, stain with osmic acid or Sandan III solution.

Employing this method, the writer found neutral fat present as shown in the accompanying table.

TABLE No. X.

Normal fluid: *2 cases;* trace—absent.
Delirium tremens: *12 cases;* varying amounts found—
0.7%—0.3%—0.5%—0.12%—0.8%—0.1%
0.4%—0.7%—0.3%—0.3%—0.5%
Concussion of Brain: negative.
Fracture of skull: 0.9%
Eclampsia: 0.2%
Acute anterior poliomyelitis: *2 cases;* in one immediately after onset 3.9%, later after subsidence of meningeal symptoms 0.3%—the other case 0.9%
Chronic hydrocephalus: *3 cases;* 0.2%—0.6%—trace.
Tumor (T. b. c.) of cerebellum: .01%—(trace).
Amaurotic idiocy (family): 0.3%
Cerebral embolism: *1 case;* three examinations during height of meningeal symptoms—negative twice—just after the symptoms subsided—0.9%
Tuberculous meningitis: *6 cases;* 0.1%—negative—0.6%—0.1%—0.7%—0.1%
Meningococcic meningitis: *2 cases;* in one with very marked symptoms 3.9%—the other 0.3%
Purulent (otitic) meningitis: *4 cases;* those with pressure symptoms predominating=2.4%—2.4%—the other, with great prostration but no marked pressure symptoms=0.6%—one only showed trace.

The writer prefers to publish these findings without detailed comment at this stage of his investigation since much additional material remains to be studied before conclusions are warranted on the relation of the increased percentages of neutral fat present in the given fluid to the clinical picture in the given case. It is noteworthy, however, even at this time, to observe the high percentages found in cases of anterior poliomyelitis (bulbar type). Likewise in the purulent otitic meningitides, both of which terminated fatally, the percentages of the fat found were more than one per cent. Here, for the present, we leave this question. The results are published to stimulate other observations along similar lines, for only from the study of a large amount of material can conclusive deductions be drawn, and at the present there is no basis in the literature upon which to build.

Summarizing the evidence thus far presented, it is found that, due to bacterial activity plus the factors discussed in preceding sections of this paper, there exists in meningitides a decomposition of the lecithin molecular element in the nervous tissue. The evidence of this is presented in the cerebro-spinal fluid through the finding in it of larger quantities of cholin than the amount which we term the normal minimal trace. From all the evidence presented by detailed investigations of this alkaloidal body it seems to be the factor in the clinical picture which we, as clinicians, have

come to regard as the "poison-effects" of the disease. Furthermore, the increased quantity of cholin in cerebro-spinal fluids of meningitides is not the result of gross destruction of the lecithin constituent of grey matter in the brain so much as it is another evidence of the stasis of circulation of the cerebro-spinal fluid, with the result of an accumulation of the products of cell metabolism, because the mechanics of elimination are interrupted. This is shown by the decrease in its amount and the absence, or disappearance, of the toxic-poisoning effects later, when the patient begins to recover.

Finally, there is preliminary report of evidence of the presence of ultimate decomposition products from lecithin disintegration in the finding of a neutral fat in higher percentages than one per cent in cases whose course terminated fatally.

Before proceeding with the disposition of the remaining questions raised in our first general proposition concerning meningitides, it might be well to call attention to other findings in the cerebro-spinal fluid, and to the significance which attaches to these abnormal ingredients.

In the first place, as already indicated in a preceding section of this paper, the exact, careful bacterial examination of the fluid by smear from centrifuged sediment, and from culture inoculations, are not to be neglected in seeking evidence of disease,—but here attention is called more particularly to those chemical characteristics found in disease which very often will help toward diagnosis in the face of negative microscopical results, or long before such results are obtainable; for, if the premises of these arguments are substantiated, interference will have to be an early resort if recovery is to result; and therefore any facts obtained which throw light on the diagnosis of meningitis are of value.

The methods of cyto-diagnosis introduced by Sicard, Widal and Ravaud, have been alluded to, and the significance of the cytological examination of the fluid given in the monograph of Kopetzky in 1906. Recently Kaplan details a method of analyzing the numbers and characters of the cells in the fluid. According to Kaplan, any fluid showing more than 8 cells to the cmm. is significant of some sort of pathological change in the meninges.

Albumen is also found in appreciable amounts in the fluids from meningitis. The amount of protein is variable. Its presence as a chemical finding in spinal fluid is not, however, limited to meningitides as it has been demonstrated to occur and its amounts estimated in a variety of diseases (Fraenkel-Heiden). The writer

places more significance on the finding of an excess of globulin in the fluid, but usually the results of tests show both constituents running in parallel amounts.

In estimating the globulin excess, the following method, devised by Kaplan, was employed. This method is a modification of the procedures of Nonne, and Noguchi, and has been found entirely practical.

1. Centrifuge the fluid, and use only the supernatant part in the test.

2. Into each of five small test tubes respectively introduce from 0.1 ccm. to 0.5 ccm. of clear fluid (no admixture of blood must be used).

3. Heat first tube (0.1 ccm.) gently and add 2 drops of a 5 per cent butyric acid solution, and heat until it bubbles,—but does not spurt.

4. Holding tube almost horizontal, permit 0.5 ccm. of a supersaturated ammonium sulphate solution to meet the cerebro-spinal fluid.

5. Stand aside, noting the time when last portion of ammonium sulphate was added to the 0.5 ccm. tube, each tube respectively having been treated as above described.

In the case of a protein excess, a distinct ring appears in the middle of the fluid, in from 5 to 25 minutes, of a coarse, granular appearance (cheesy) and of a cream color. The greater the protein contents the more apparent the appearance of the ring in the tubes with the smaller amount of cerebro-spinal fluid. The rings appearing later than 25 minutes are not characteristic.

The writer employing this test was enabled to substantiate the statement of Hammerstein that the protein contents of fluids in cases of meningitis was increased. Not enough material was examined to correlate the findings with clinical observations, except that the cases with most marked symptoms, and also which terminated fatally, uniformly gave the highest figures.

Our finding of variously estimated quantities of *lactic* acid in the spinal fluids under examination deserves some special study. In 1905, Zweiful found this acid in the blood and the urine of the mother, and the blood of the umbilical cord of the infant in cases of eclampsia. He believed the stormy clinical picture of eclampsia due to the presence of this acid. Since then, lactic acid has been found under a large variety of conditions;—in cases of leukemia, phosphorus poisoning, acute atrophy of the liver, in both spinal

fluid and the blood stream. Finally it was studied in its relation to the clinical picture of epilepsy by Lockermann, Zweifel, Fueth and others.

The finding of lactic acid in cases of eclampsia (ten Doesschate), epilepsy, pulmonary disease (Irisawa), meningitides, hyperemises gravidarum (Underhill);—all in cases which give evidence of a general systemic "poisoning effect," led the writer to study the clinical picture in correlation to the findings of the acid in the fluids under examination to ascertain whether those cases of meningitides which gave the larger amount of lactic acid were also of those presenting the more stormy clinical course. The evidence of a definite relation was not entirely satisfactory, because it was not always possible for the writer to follow up in detail the clinical side of the case, but from those observed he feels that there is more than presumptive evidence of the fact that lactic acid was found more abundant in the cases which showed the more pronounced symptoms of general prostration.

Regarding the formation of the lactic acid from the carbo-hydrate element of the fluid, satisfactory evidence is also lacking. This much is shown, however,—quantities designated as "marked" (see Section III) and found occurring in non-meningitic cases, such as, for example, anterior poliomyelitis, meningisms, etc., nevertheless gave the presence of lactic acid and *also* the presence of the copper reducing body,—the carbo-hydrate. The writer is therefore inclined to disagree with Hammersten's and Abderhalden's statements that the *carbo-hydrate and* the albumin furnish the source of the lactic acid in the fluids from non-meningitic cases, and while conceding that the fermentative activity of the bacteria in the fluid may break up the carbo-hydrate element and thus partly account for the presence of lactic acid in the meningeal infections, yet the preponderance of evidence from all sources would indicate the origin of the acid as coming from the protein element, especially since in meningitis we have, as already shown, a state of lack of oxygenation as a prime factor in the tissues affected by the disease.

Regarding the inorganic compounds demonstrated in the fluid,—there seems to exist a variable antagonism between the quantities of potassium salts and the sodium salts of the fluids. Yvon gives the figures NaCl. 7.098 and KCl. 0.033 per 1000. F. Mueller places the relationship of NaCl. to KCl. as 21.5:1, according to Salkowski, the variable relation between the potassium and the sodium salts is probably due to the presence or absence of fever during the forma-

tion of the exudate. Since, as Halliburton and others point out, the amounts of the potassium salts are practically negligible in normal cerebro-spinal fluid, the significance in the finding of increased amounts of potassium salts in given cases permits the deduction that an exudative process is under way. The writer invariably found the potassium salts present in appreciable quantities in the fluids from meningitides, and this finding in the absence of a report on the bacterial contents, or in the face of a negative bacterial report was always later substantiated in a subsequent diagnosis of meningitis, clinically evident.

Finally, to check up all the findings from the chemical analysis, an idea of the amount *in toto* of oxidizable constituents in the cerebro-spinal fluid was undertaken. The method employed was that devised by Mayerhofer, and termed by him the estimation of the "meningeal index."

The test is very reliable and depends on the oxidation of compounds in the fluid by potassium permanganate. The procedure is as follows:

1. Heat 1 ccm. of cerebro-spinal fluid after adding 50 ccm. of distilled water and 10 ccm. of a 25 per cent solution of sulphuric acid

2. Just as this boils, add 10 ccm. of n/10 potassium permanganate solution and keep the whole simmering for 10 minutes.

3. Then add 10 ccm. of n/10 oxalic acid solution, when fluid will at once become limpid and clear.

4. Then add drop by drop more n/10 potassium permanganate solution until the first drop leaves a distinct and *permanent* rose color trail.

Calculate the number of ccm. of additional potassium permanganate used and this figure is the index sought.

In Mayerhofer's results, the index for meningitides was always found to be above 5. The writer's investigations show that fluids from non-meningitic cases,—meningisms, sepsis, etc.,—are found between 1 and 3, while the indices from meningitides was invariably found at 4, or above it. This slight variation in results may be due to the personal equation, which becomes an element when terminal color reactions are estimated by different individuals.

A low meningeal index is therefore significant of the probable absence of meningeal infection, while the higher figures speak for the probable diagnosis of meningitis in the given case.

In the consideration of the questions of brain and meningeal tissue edema, the possibility that the key to the first factor in the vicious cycle of events in the causation of the stasis of the cerebro-spinal fluid and its failure to readily penetrate the membranes of the Pacchionian bodies, because of a change in the internal tension of the fluid itself, was given thought, and a study was made of the specific gravity of the cerebro-spinal fluid. The results of the cases examined failed to give an adequate answer to the questions at issue, however. The results obtained are given below.

The specific gravity was measured with a Westphale balance, the determinations corrected to temperature of 15° C., and were as shown in Table XI.

TABLE XI.

Normal fluid	2	specimens;	1006, 1007
Delirium tremens	7	"	1003 to 1006
Typhoid fever	1	"	1006
Tuberculous meningitis	6	"	1001 to 1007
Meningococcic meningitis	4	"	1007 to 1009
Purulent (otitic) meningitis	4	"	1001 to 1007
Anterior poliomyelitis	5	"	1007 to 1008
Cerebellar (T. b. c.) tumor	1	"	1006
Meningism	3	"	1006
Cerebral embolism	3	"	1004 to 1008
Chronic hydrocephalus	3	"	1006 to 1007

While no definite conclusions are to be deducted from the study of the specific gravity of the fluid, the generalization is possible that in purulent meningitis the specific gravity was found to be in some relationship to the turbidity of the fluid, the more turbid giving the higher specific gravities. The fluids from tuberculous meningitides were found to present the lowest specific gravities. Following the centrifugation of the fluids, the specific gravity was apparently changed. These results are added to the other chemical findings because even negative results from an investigation have scientific value.

In concluding this section the writer desires to emphasize that too much reliance must not be placed on any one constituent found in the cerebro-spinal fluid, but that the results of the total examination shall be the basis of any diagnostic data, and the results of the chemical examination alone are not to be the criterion but these must be studied in addition to the results of cyto-diagnosis and bacterial investigation.

It is not within the scope of the arguments presented in this paper to indicate fully the relative significance of the abnormal

constituents in the spinal fluid except as they bear fruit relative to the aspect of meningitis presented in this paper. These questions present much of scientific interest and will receive attention in subsequent papers. Here, for the present, we will leave the question of the significance of the chemical findings in the cerebro-spinal fluid to return to the consideration of the problem which is the subject of our investigation.

VI.

In dealing with the questions at issue in presenting the arguments that meningitis is to a certain extent a progressive disease we at once encounter difficulty in the attempt to bridge the gap between the so-called "meningitis serosa" and those meningitides which exhibit frankly purulent characteristics due to demonstrable micro-organisms in the spinal fluid.

In the first place, every otologist has had under his care cases which have shown a more or less complete set of clinical pictures logically referable only to an involvement of the meninges. Such cases often completely recover without requiring any other treatment than the removal of a diseased foci in the tympanic cavity and mastoid process. Lumbar punctures performed in such cases give a fluid which, in the average, is reported as clear, and when examined for it show no micro-organisms culturally demonstrable. The literature lacks reports of complete analyses of the fluids in such cases, i. e., an analysis including examination of the physical, chemical, cytological and bacterial characteristics.

In the second place, for obvious reasons, such cases rarely reach autopsy. A summary of the findings which are published seems to show no demonstrable lesion in the central nervous system except an evident increase in the amount of cerebro-spinal fluid, flattened convolutions, and distended ventricles. The keenest examination will reveal at most only a cloudiness of the pia mater.

The case reported by Swain represents, to the writer's mind, an advance step in the evolution of the disease. Here the only lesion found at autopsy was some pus on the choroid plexus in the ventricle.

An interesting case showing a clinical picture of meningitis, with recovery, and presenting points of special interest to our argument, is that reported by von Beck:

Boy, 14 years, suffered since he was 7 years old with an intermittent otorrhea. January 22, 1894, he was attacked by headache, and earache

(right). Had no fever, but vomited. January 25 became unconscious. Status on January 26: a pale youth, semi-comatose, at times crying out, and boring his head into pillows. Exophthalmos present, pupils normal in reaction but choked disc more markedly present in the right eye than in the left. Hyper-esthesia and hyper-algesia of the entire body, no paralyses; percussion of the head more painful on the right than on the left side. Nothing noted regarding the mastoid processes; no otorrhea; membrana tympani thickened, red, and showing a small scar. Temperature 37.80°, pulse 60. January 27, temperature 36.8°, pulse 52. Somnolent. Operation by Czerny. Exposure of sinus transversus, which did not pulsate, but contained normal blood. (Puncture test). Dura mater over tempero-sphenoidal lobe tense and without pulsation. Puncture of the lobe through the dura without results. Puncture of lateral ventricle delivered 4 ccm. of a water-clear (wasserhelle) fluid which, after withdrawal of the needle, flowed in a slowly pulsating stream until about 26 ccm. was evacuated. After the operation, pulse 80°, no fever.

January 28: Sensorium much clearer, lessened headache, appetite good, and restful sleep. Was in general good condition until February 2, when headache returned, improving somewhat when ice was applied. February 4: again headaches, and vomited twice. Pulse. 68. February 5: Pulse 44. Cloudiness of sensorium, opisthotonus.

Second operation: Dura again found without pulsation. Puncture of the temporal, frontal and occipital lobes through the old wound, searching for an abscess, was without result. When the puncture was carried directly inward, 40 ccm. of cerebro-spinal fluid again obtained. February 6. Patient now has no symptoms at all. Pulse 80.

February 7. All the old symptoms again present, and in the next few days evidenced symptoms of increased intra-cranial pressure.

Third operation was performed on February 15. Again 40 ccm. of cerebro-spinal fluid was removed from the right lateral ventricle; that same evening the patient was decidedly improved. Headache persisted, however, until February 22. From February 23 onward improvement continued until discharge from clinic, March 18. Control examination February 11, 1896, and found normal.

Where, in the usual run of these cases as we see them, the meningeal symptoms disappear after the removal of the primary foci of disease, *the correctness of the diagnosis—"meningitis"* is sometimes called into question. In the case cited above, however, where the symptoms reappeared three distinct times and receded each time upon the institution of therapy which relieved the pressure symptoms, the diagnosis cannot be questioned. Furthermore, when, for long periods of time after the relief of the acute onset of meningeal symptoms, traces of disturbances in the meninges remain as evidence of their involvement, the correctness of the diagnosis receives further support. It is our purpose to cite a few cases illustrative of this point. The histories are contracted into as brief a

description as is possible to present their salient features. Those further interested in the detailed histories are referred to the bibliography accompanying this article.

The next case, reported by Robson, also recovered,—but from the symptoms it is shown that adhesions took place, and so it is reasoned that a further advance in the meningeal process is shown from the simple excessive accumulation of clear spinal fluid in the intra-cranial space:

The patient was a girl, aged 10 years, taken sick with pain in the left ear and left side of the head, in December, 1888. Toward the middle of January, 1889, rigidity of the head became noticeable, and there were spasms of the muscles at the angle of the mouth, and also a light delirium. January 18, 1889; Temperature 41.0° C. January 19, admitted to ward. Restlessness; no delirium; but "raiae meningitique." Temperature 40.0° C. Pulse very much slowed. Left side otorrhea and tenderness over the mastoid process. January 22, 1889. Continuous talking, sleeplessness—but apparently without pain. No otorrhea now. No neuritis optica. January 29. Temperature normal; frequent pulse rate (not exactly stated). February 5. Again fever; also *hemiplegia dextra* accompanied by *aphasia*. Enlarged pupils, *double optic neuritis*.

Operation February 6: "Trepanation" over arm-center. Incision of dura. Brain without pulsation. Tested by puncture in various directions without result—then puncture of lateral ventricle, evacuation of 22 ccm. of serous fluid. At once return of brain pulsations. Suture of the dura. The next morning patient was able to move arms, and gradually all the paralysis disappeared. After a month all evidence of hemiphegia was gone. (No report on the aphasia), (published in January, 1890), and at time of report patient was in good health, although occasionally she exhibited spasms in the right arm.

The next case has been selected because it gave a slightly *turbid* fluid, although here, too, recovery was obtained. The case again evidenced an advance in the evolution of the disease, and is evidence of the progressive nature of meningitides.*

A woman, 51 years of age. June 5, 1895, attacked with chills, dizziness, malaise, and general pains in the limbs; during the night, pain and tinnitus in the right ear. June 13; headache localized to occipital region. Drum (right) red and slightly bulging, otorrhea present. Has symptoms of dizziness, and sensorium is not entirely clear. Temperature 40.1° C. Paracentesis.

June 17: patient apathetic, presenting photophobia; occipital region tender to percussion; no rigidity of neck or head; eye-grounds—engorgement and some discoloration in veins at periphery of disc.

Mastoid operation on June 27—no pus in antrum. The following night—chills, otherwise nothing of note except continuation of fever. Pulse slower, 70-88.

*From Boeuninghaus.

July 3: Increase of headache, and cloudiness of sensorium. No opisthotonos. Next night gave delirium.

July 4: Exposure of sigmoid sinus and opening of it; the sinus had been compressed by the intra-cranial pressure and appeared as if empty of blood; no pulsation of dura over cerebellum. Removal of tegmen revealed that no pulsations were present in dura of cerebrum. Wide incision of the dura made, and incision also made into the brain substance, which at once sprang into the dural opening. The brain tissue was also pulseless, and appeared anemic (blutleere Hirnsubstance). Nowhere was pus discoverable. Puncture of the lateral ventricle now performed, evacuating about 10 ccm. *of slightly turbid* fluid. Thereupon slight pulsations of the brain came on, and the *Pial blood vessels were seen to become filled up with blood.* Immediately thereafter fever dropped and the general condition improved, recovery taking place. (No report on the examination of the fluid is given).

Additional cases are reported with slightly differing details by Waldvogel, Dench, and others. The following case is given here because the author of the report gives a rather detailed description of the conditions he found at operation. The case further shows the progressive nature of meningitides, and here we have a reported observation from the operation-table showing that the brain edema was evident to the naked eye at that time. The brain prolapse simulates the finding on our dogs with experimentally induced cerebral anemia. The case is reported by Joel as follows:

Boy of 12 years; was attacked, during the course of a long-standing otitis media purulenta chronica, in May, 1893, with headache, dizziness, and vomiting, and general malaise. These symptoms continued without the occurrence of any fever, with occasional recessions, until June 12. Then the patient exhibited intense general spasms, with loss of consciousness, lasting the entire day. The spasms commenced in the muscles of the face, then spread to the arms and the legs.

Operation: In addition to the radical mastoid, "trepenation" was performed over the temporal lobe. *Dura very tense and pulseless.* After incision of the dura brain tissue protrudes into wound. Pia is intact, but strongly hyperemic. Multiple incisions of the cerebrum 4-5 cm. in depth gave no evidence of pus. The brain tissue is observed to be *extraordinarily edematous*, moist, glistening (glaenzend) and soft, and formed a hernia. The spasms stopped immediately; the sensorium cleared the middle of the next day. Pulse and temperature became normal. Three days later change of dressings. The brain prolapse gave no reaction. There was a slight aphasia. Brain prolapse removed June 27. In two months recovery completed. Control examination after two years found patient healthy and normal.

And so cases might be multiplied. It is of interest, however, to record some cases where the lesion seems to localize itself to a

circumscribed area, judged from the clinical symptoms presented. Thus, Merkens reports an interesting case which presented marked aphasia for some time after recovery had taken place, while, during the period of active meningeal symptoms, in addition to the aphasia there were shown unconsciousness, fever, and clonic spasms involving one whole side of the body. The eye-grounds, too, evidenced symptoms which we now account as due to intra-cranial pressure. Koerner* records two interesting cases which can be grouped here. The one showed a *paralysis of the right arm and hand*, which lasted from December 19, 1891, (accompanied with other symptoms referable to the meninges—headache, vomiting, fever, and eye-ground picture of distorted boundary of disc, and engorged blood vessels) until December 24, when all symptoms disappeared. The second case, besides the usual meningeal symptoms, showed *double vision*, and on the one side abduceus paralysis. On April 22, 1901, the eye-ground examination, which had given normal findings on March 31, 1901, when patient was admitted, now showed a swelling of the optic papile equal to one diopeter, and also optic neuritis. These symptoms all disappeared at the end of the same year.

In addition to these cases, the writer details a case which came under his personal care on October 8, 1910. The case demonstrates the fact that in these early stages of meningitis the focal signs may be drawn from the spinal cord as well as from the brain, any part of the investing membrane possibly being the focal seat of a lesion, a little more advanced than the inflammatory reaction affecting the meninges as a whole:

On October 6, 1910, there came under my observation at the Manhattan Eye, Ear and Throat Hospital a child of 5 years, giving a history of having had a purulent otorrhea on the *right side* since infancy. Fever had developed three days before appearance at the hospital. During the night previous to appearance at the hospital *facial paralysis had suddenly appeared* on the *left side*. *Status on admission*: Comatose child, with profuse otorrhea of right ear, no mastoid tenderness elicited. Temperature 103.4° F., pulse very rapid, head thrown backward, slight rigidity noticeable. Pupils *not* reacting to light, unequally dilated, the left larger than the right. Examination of left ear showed only reddened drum. The left side of face paralyzed, except muscles at angle of the mouth. The eyes gave *spontaneous nystagmus*, both horizontal and oblique. The direction of a slow and fast component was not demonstrable.

Rotation tests, with child held in varying positions showed a normal functionating labyrinth on both sides. Lumbar puncture gave a clear fluid, culturally sterile, and without pus elements.

*The cases taken by the writer as examples are from the older literature, and are easily available in either Koerner or Boenninghaus' monographs.

Operation, immediately undertaken. On left side, simple mastoidectomy performed. This was in the nature of an exploration as all the signs pointed to this side. Nothing abnormal found. No pus in mastoid process. On the right side, the radical mastoid operation was performed, giving the usual detritus and pus from an acute exacerbation of a chronic mastoiditis. The labyranthine wall was carefully examined and nothing abnormal recognized.

October 7, 1910: Temperature 100°. Spontaneous nystagmus still present. October 8, 1910: Temeprature normal. Spontaneous nystagmus disappeared. Child fully conscious, eyes reacting to light, and apparently in a normal condition. During the day, however, and without temperature elevation, a condition of kyphosis developed, the back becoming so rigid that patient can be placed on hands and knees and is unable to change its position. The kyphosis seemed to affect the upper region of the spinal column principally—the cervical and thoracic regions. This condition resulted in a consultation with a pediatrician, who gave it as his opinion that the child might be developing Pott's disease.

October 10, 1910. The kyphosis has disappeared. October 15, 1910. The further uneventful recovery commenced. Control examination after three months, shows entire recovery.

A critical reading of the cases collected by Koerner, Boenninghaus, and others, gives the idea that the progress of these cases has been arrested promptly on the institution of repeated lumbar puncture, or ventricular puncture in addition to the removal of the primary diseased factor in the ear. Had the condition progressed unchecked, it seems reasonable to suppose that a frankly purulent meningitis would have terminated the picture. This is presumptive evidence. An analogy might be made with a pleurisy with serous effusion which, by the compression it exercises on the structures, interfering with their blood supply, so lessens their tissue resistance that eventually it terminates as an empyema of the pleuritic cavity. Furthermore, when the fluid is drawn from the cases of so-called *fulminating type of otitic meningitis,* it is usually found clear in the first examination if this be taken early enough. Later,—if more than two days intervene before the fatal termination,—pus elements and sometimes bacterial growth is shown. Is it not reasonable to suppose that were such a case to come to autopsy from extraneous causes, and without a clinical diagnosis of the meningeal disease, that the necropsy findings would be exactly similar to those obtained in an autopsy report of an ordinary case of so-called meningitis serosa? The disease develops so rapidly in the so-called fulminating type that the fatal termination precedes the formation of a demonstrable lesion, and one examines such brains and hardly can be brought to a realization that the disease

had its seat in the endocranium. Finally the writer has observed successive fluids at a day's interval, the first negative, the second only showing bacterial growth, both clear, and the case meanwhile terminating fatally. With the emphasis which the writer places on the chemical examination of the fluid in addition to the cytological and bacterial examinations, he hopes more evidence will soon be presentable to further substantiate the idea of the progressions of meningitides from an inflammatory reaction in the tissues which is at first purely an outpouring of excessive fluid, and then, unless the progress of the disease is checked, a purulent exudative process. Merkens was the first to see that the general idea heretofore maintained regarding serous meningitis needed revision. He takes into account in his argument the edema of the brain tissue, and he makes an analogy with the tissue area surrounding a furuncle. This area is one of tissue edema which is culturally sterile. Later it may hold micro-organisms, and he draws the parallel between the infected area in the ear-spaces and the surrounding edema as embracing the brain and meninges in our cases of "meningitis serosa." The writer thinks that the expression of the factors in the production of the brain edema are amply proved in the earlier sections of this paper, and while according Merkens credit for recognizing the factor of brain tissue edema, yet the analogy is not a good one in many respects as explanatory of its existence, for, if the analogy of Merkens be granted for the sake of argument, then one would expect the edema of the brain tissue to be more in evidence on the side and near the site of the primary disease, which those who have exposed and incised the dura in such cases have not found to be the case, nor do the symptoms show a localization either, and finally autopsy reports (see Jansen) in rapidly fatal cases of meningitides following acute labyrinthitis demonstrate the general character of the edema.

Finally, Koerner has taken a new position on this question in the "Nachtraege" to his book, in which, when summarizing, he says:—"When micro-organisms or pus, arising either from the middle-ear, the labyrinth, or the mastoid process, or from an extra- or intra-dural abscess, or from a brain abscess, or sinus thrombosis, reaches the meshes of the pia it does not always follow that the pia mater *immediately* becomes affected. Organisms of low virulence can propagate in the sub-arachnoidal space and spread in the cerebro-spinal fluid to the ventricles and to the cord. The toxic substances produced by their growth, acting as irritants, cause an increase in the leucocytes in the cerebro-spinal fluid, and

also may produce symptoms which can hardly be differentiated from a fully developed meningitis. Such cases at autopsy do not show inflammatory changes or pus in the meninges * * * *Without doubt, we are here dealing with a very early stage—initial stage* (Vorstufe) *of purulent lepto-meningitis."***

From what has been presented in this section, the presumption is reasonable, and the *conclusion is justified*;—even in the absence of direct evidence to support it—*that in meningitis we are dealing with a disease whose nature is progressive, which may terminate in recovery in its very beginning, or initial stage; or, if it advances, it eventually exhibits those frankly purulent characteristics which have caused the later stages to be termed "purulent meningitis."*

In reality, therefore, the consideration of the various stages as separate and distinct entities is due to the study and classification of different stages of one disease in varying periods during its evolution. Of the classification of meningitides according to the causal microbe, no discussion is needed, besides the question of classification does not concern us in this article.

VII.

CONCLUDING REMARKS.

From the study of the interwoven problems presented above, we note that the factors which underlie our clinical picture are the same in all the so-called types of meningitides. Inherent differences due particularly to the specificity of given microbes play no part in the factors studied in the aspect of meningitis here presented. The toxic, and the poison-effects from infection of the tissue and fluids of the central nervous system are due to the same tissue-reactions whether the pathogenic microbe in the given case is a meningococcus or a streptococcus, provided only that sufficient numbers of the organisms gain a foothold and the results of their growth become operative on the tissues of their host.

As a result of this invasion of the fluids and tissues of the central nervous system, the available carbo-hydrate in the spinal fluid, is used up, and disappears from the fluid. The disappearance of the copper reducing body, excepting in the slowly developing tuberculous meningeal infections, is probably the very earliest sign of the activity of the bacteria in the central nervous system. Thus there is afforded us means of diagnosis, in cases of suspected meningeal

**Free translation from the German text.—Italics are mine.

infection, which clearly differentiates meningitis from all other diseases whose clinical pictures give symptoms habitually referred to the meninges, as, for example, the meningeal signs of general sepsis (including otitic sepsis), the meningeal symptoms of pneumonia or typhoid fever, etc.

The underlying primal factor which influences the *onset* of the series of events, constituting the vicious cycle remains as yet undermined. We have, on the one hand, the increased amount of cerebro-spinal fluid, and on the other, the edema of the brain and meningeal tissues acting against each other within the limited available space of the cranial vault, and both factors exerting a compression-force on the blood and nutrient supply and thereby tending to further increase the edema:—in the face of these conditions we are forced to accept, tentatively at least, the theory that in the use of certain constituents of the spinal fluid, by the microbes as dietary;—a change in the composition of the fluid results, changing its tension, and thereby its permeability through the membranes of the cellular elements of the Pacchionian Bodies and that thus there results *a stasis* in the circulation of the cerebro-spinal fluid;—the first factor in the production of symptoms of meningitis.

The interference with the circulation of the cerebro-spinal fluid, and the compressed arterial blood supply, produces an anemia, with the resultant picture of increased intra-cranial pressure. When the intra-cranial tension reaches a sufficient degree, the "fight for existence" of the vital centers start, bringing in its train the significant signs from the vaso-motor, the respiratory and the vagus centers. Meanwhile, due to the same factors, an acidosis of the tissues results, and in the spinal fluid we find evidences of this, in varying degrees of acidity, and the presence of differing amounts of lactic acid.

The metabolism of the cellular elements of the tissues involved are incidentally interfered with to a degree that their chief constituent undergoes degeneration, and the alkaloidal poison-groups, characterized by cholin, accumulate in the spinal fluid and add direct nerve-poison to the deleterious products of direct bacterial activity already present, and the case gives signs of this in the symptoms of toxicity, and prostration exhibited. Later, the further decomposition throws neutral fat into the solution, as further evidence of the destruction of nerve-tissue elements. The results of our study, therefore, demonstrate that the symptoms of meningitis fall into two general subdivisions: 1. Those dependent on in-

creased intra-cranial pressure. 2. Those dependent on the growth of bacteria, and on the decomposition products thrown into the circulation from the disintegration of nervous tissue. The former, more often than the latter, determine the outcome in the given case.

Therapeutic measures necessarily accomplish but limited results when their aim is control only of the symptoms referable to the second subdivision of the symptom-complex, and we can the better understand the persistence of a high degree of mortality in meningitides, which continues in the face of specific sera, antitoxins, vaccines and other agents (urotropin injections, etc.). On the other hand, as Horder has pointed out, even resolution in epidemic cerebro-spinal meningitis after lumbar puncture complicates the therapeutic argument in connection with the use of specific sera and vaccine. Results are sometimes put down to the credit of these substances which it is not unreasonable to suppose were due to the withdrawal of some of the inflammatory exudate from the spinal canal. In addition, the cases of meningitis which have yielded to repeated lumbar puncture, and to ventricular puncture, without administering any agent to combat the microbic activity, gives added significant evidence to substantiate this contention. In our literature, only pure streptococcic infections of the meninges has been uniformly fatal. Furthermore, if we critically read the preliminary report just made by Soffian of his observations taken in the recent epidemic of cerebro-spinal meningitis in Texas, we note that in all the cases, except those he terms "hopeless from the start," he reduced the intra-cranial tension to as near normal as possible before injecting his serum. Thus he succeeded in breaking the vicious cycle,* and often, contrary to what he expected, he finds, following his injection of the serum, instead of an increase of intra-cranial tension, demonstrated by a rising blood-pressure, a fall of blood-pressure, and therefore a fall in intra-cranial tension. We have in this an added observation, that a reduction of the cerebro-spinal tension and the use of serum were the factors which controlled the situation and gave results characterized by Soffian as "unusually good." Finally, to present an idea of the amount of pressure reduction possibly achievable by the simple procedure of lumbar puncture, we give the evidence of Frank J. Sladen of the Johns Hopkins Hospital staff, who determined that the re-

*The reasoning is mine. Soffian promises a later report detailing his reasons for this finding, based on Cushing's work. In this article, Soffian simply states the facts as he observed them, making no additional comments.

moval of 30 ccin. of fluid reduced the pressure 300 mm.,—or, one ccm. of fluid withdrawn equalled a reduction of 10 mm. of pressure (water).

Finally the cases whose rapid course—fulminating types (meningococcic) and (otitic, streptococcic)—hardly give time to institute remedial measures before the paralytic phenomenon from the vital centers terminates the case, always show the symptom-complex as dominated by the intra-cranial pressure symptoms.

From all this, the conclusion is inevitable that any procedure which places the control of the intra-cranial pressure within our grasp will be the logical surgical remedy for this condition. The pressure factors once in hand, then the added forces we can bring in the form of sera, antitoxins, and chemical agents, may find increased value in combating the symptoms referable to the second subdivision of our symptomatology. Thus we would have all factors covered in the given case.

Efforts have already been made, and methods tried out, and a simple and easily performed operation has been perfected in all its details. The credit for working out the ingenious technic belongs more properly to my associate in the work, Dr. Irving S. Haynes, of Cornell University Medical College. In another article which appears simultaneously with this one, he presents all the available data on the questions and problems of the surgical treatment of meningitis.

Three cases have come under my observation in connection with the new operation. Two of these cases were seen in association with, and operated on by Dr. Irving S. Haynes and the third was turned over to me, by Dr. Wendel C. Phillips, for the performance of the operation. This was one in which the meningeal infection followed an acute mastoidal and acute labyrinthine purulency, and, from comparison with the course taken in parallel cases, would have been of the fulminating type. The causal microbe was the streptococcus. *I operated to drain the cisterna magna.* The patient survived the mastoid and labyrinthine exenteration, and the operation for drainage of the cisterna magna (all performed at one stage) for nine days. During all this time *sensorium remained unclouded,* there was *no delirium,* even to the end; no retraction of the head, and no rigidity. The pulse-rate varied, and the blood presssure was kept within bounds by re-establishing a flow of cerebro-spinal fluid from the cisterna magna, when evidence of its rise above 120 mm. Hg. was presented. The details of all these, and

other cases, are now being prepared for publication. A description of surgical technic is not within the scope of this article.

In conclusion, this study of meningitis, while not bearing directly on questions appertaining to diagnosis, would lack completeness did we not emphasize those of our findings which help toward making an early diagnosis; for if surgical measures are to meet with any degree of success in meningitis, *the condition must be recognized early, and the relief instituted promptly.*

The early diagnosis, according to our findings, besides those manifestations of meningeal involvement which we, as clinicians, are wont to recognize as such, lies in the *repetition at short intervals of blood-pressure estimations,* a progressive increase in which is the first significant sign. The eye-ground examination, giving a *finding of an increased tension in the veins, swelling of the papilla,* is next in importance. The *examination of the spinal fluid, completed in all its details,* gives the final necessary determination. The pressure of its flow is noted, its physical, chemical, cytological, and finally, its bacterial constituents determined. The chemical examination gives the quickest answer, and the *absence of a copper-reducing body,* a degree of acidity, the presence of lactic acid, albumin, and globulin in addition to the estimated increase in potassium salts, and the finding of larger amounts of cholin than normally present, or a high percentage of a neutral fat, or both;—these make for a diagnosis of meningitis. Later, the cytological and the bacterial examinations bring added data, but in the event of negative bacterial findings, and positive increase in cellular elements, and a fluid which apparently is "clear," and yet gives as a result of chemical examination results as outlined above,—then there is a strong presumption that the given case is one which is a menigitis, which presumption becomes stronger if the bedside observation substantiates these findings, by demonstrating increasing blood-pressure, and other signs. It is to be noted that the chemical signs of a meningitis are obtainable some time before any other reports from the examination of the fluid are available.

With this brief outline, by way of emphasis, on the value of the chemical examination, we will end our discussion on the many questions involved in the consideration of the problems of meningitis.

BIBLIOGRAPHY.

ABDERHALDEN (HALL): Text-book of Physiological Chemistry (1908).

ALTHANN: Cited by Hammersten.

ARAKI: *Zeitschrift fur Phys. Chem.*, Bd. 15, 1891; *Zeitschrift fur Phys. Chem.*, Bd. 19, 1894.

ARCHIBALD: American Practice of Surgery, Bryant and Buck, Vol. 5, *Montreal Medical Journal*, No. 34, 1905.

ASTASCHEWSKY: *Zeitschrift fuer Phys. Chem.*, Bd. 4.

ATKINSON AND FITZPATRICK: *Proc. Soc. of Exp. Biol. and Med.*, Vol. 7, 1910, pp. 146, 147.

BAUMGARTEN: *Lehrbuch der Pathogen. Microorganen*, 1911.

BENEDICT, S. R.: *Jour. A. M. A.*, Vol. 57, No. 15.

BECK, VON: *Mitteilungen aus d. Grenz d. Med. und Chir.*, Bd. 1, 1896.

BERGMAN: Die Lehre von der Kopfverletzungen, *Deutsch. Chir.*, Lief 30; also *Handbuch der Praktische Chir.*, Vol. 1.

BIENSTOCK: *Arch. f. Phys. Chem.*, Bd. 36.

BRIEGER: Ueber Ptomaine (Hirschwald) 1885-1886, *Berl. Klin. Woch.*, 1887.

BOENNINGHAUS: Die Meningitis Serosa, 1897.

BRUNS: *Handbuch der Praktischen Chir.*, Vol. 1.

BRYANT AND BUCK: *American Practice of Surgery*, Vol. 6.

CANNON, W. B.: *Amer. Jour. of Physiol.*, Vol. 6, 1902.

CASSEL: *British Med. Jour.*, 1874.

CAZZINI: *Zentralbl. f. Physiol.*, Bd. 6, 1896.

CAVAZZINI: Maly's Jahrber, No. 22; *Centralbl. f. Phys.*, No. 15; Sur liquide cerebrospinal. *La Riforme Medica.* Anno. 8, 1892, Vol. 2.

CRAMER: *Arch. f. Hygiene*, 1895, No. 151.

CONNALL, ANDREW: A study of the cerebrospinal fluid in the Infective Diseases with Special Reference to Cerebrospinal Fever. *Quarterly Jour. of Medicine*, Vol. 3, (1909-10).

CUSHING, HARVEY: Physiologische und anatomische Beobachtung ueber den Einfluss von Hirncompression auf dem intracraniellen Kreislauf und ueber einige verwante Erscheinungen. *Mitt. a. d. Grenz. der Med. und Chir.*, Bd. 9, Heft 4 and 5; (also) Some Experimental and Clinical Observations Concerning States of Increased Intracranial Tension. *American Jour. Med. Science*, Sept., 1902; (also) Blood Pressure Reactions of Acute Cerebral Compression. *American Jour. Med. Science*, June, 1903.

DANA AND HASTINGS: *New York Medical Record*, Jan., 1904.

DENCH: *Zeitschr. fuer Ohrenh.*, No. 30.

DONATH: *Zeitschr. fuer Physiol. Chem.*, No. 59, 1903; *Zeitschr. fuer Physiol. Chem.*, No. 54, 1907.

DRESSER: *Zeitschr. fuer. Biol.*, No. 21, 1885, *ibid* 12, 1886.

TEN DOESSCHATE: *Zeitschr. fuer Physiol. Chem.*, No. 54, 1907.

DRYFUS: *Zeitschr. fuer Physiol. Chem.*, Vol. 18, 1884.

DURET: Etudes experimentale et clinique sur les traumatismes cerebreux. Paris, 1878.

ELSER, W. J.: Studies in Meningitis. *Jour. of Med. Research*, Vol. 20, No. 4 (New series Vol. 25, No. 4, June, 1909).

EVE: *Jour. of Phys.*, Vol. 20, p. 334.

EYSTER: Blood Pressure Changes in Cheyne-Stokes Respiration. *Johns Hopkins Hospital Bull.*, Vol. 17, 1906. Clinical and Experimental Observation upon Cheyne-Stokes Respiration. *Jour. of Exp. Med.*, Vol. 8, 1906.

FISCHER, MARTIN H.: Edema, a Study of the Physiology and Pathology of Water Absorption by Living Organisms, 1910; also Nephritis, and Experimental and Critical Study; etc., 1912.

FITZPATRICK AND ATKINSON: *Proc. Soc. Exper. Biol. and Medicine*, Vol. 7, 1910, p. 146.

FLETCHER AND HOPKINS: *Journal of Physiol.*, No. 35.

FLEXNER AND LEWIS: *Jour. Amer. Med. Assoc.*, No. 53, 1909.

FRENKEL-HEIDEN: *Biolog. Zeitsch.*, No. 2.

FUTH AND LOCKERMAN: *Zeitschr. fuer Gynecol.*, Jan. 13, 1906.

GAD: Hemorrhagische Dyspnea. *Dubois-Reymonds' Arch.*, 1886.

GAUTIER: Traite de chimie applique a la physiologie, No. 2, 1873. *Compt. Rend.*, No. 94; Sur les alcoloides derives de la destruction bacterienne au physiologique des tissues animaux. Paris, 1886. (See, also, Bouchard-Lecons sur les auto-intoxications dans les maladies. Paris, 1887.

GIES, WM. J.: *Proc. Soc. of Exp. Biol. and Med.*, No. 8, 1911.

GIEGEL: Die Mechanik der Blutversorgung des Gehirns, 1870.

GOODRIDGE, F. C.: *Proc. Soc. Exp. Biol. and Med.*, No. 8, 1911.

GRASHEY: *Festschr. fuer L. A. Buchner*, 1892.

GRUENBAUM: Cited by Halliburton.

GSCHLEIDEN: *Pfluger's Arch.*, Vol. 8.

GUMPRECHT, F.: Cholin in den normalen und pathologischen Fluessigkeit und die physiologische Function derselben. Congress fur Innere Medizen, No. 18, 1900.

GULEWITSCH, W.: *Zeitschrift fuer Physiol. Chem.*, Nos. 20, 24, 27 and 29, 1897.

HALLIBURTON: Biochemistry of Muscle and Nerve, 1904.

HAMMERSTEN: Physiological Chemistry, sixth edition, 1911.

HASEBROEK: *Zeitschr. fuer Physiol. Chem.*, No. 12.

HASSLAUER: *Internat. Centrlbl. fuer Ohrenh.* Die Mikroorganismen bei den Otogenen Endokranuelen Komplikationen. Bd. 5.

HAWK: Practical Physiological Chemistry, third edition, 1910.

HEIDENHEIM: *Centralblatt f. d. Med. Wis.*, 1868.

HILL, L.: Physiology and Pathology of Cerebral Circulation, London, 1896; Recent Advances in Physiology and Biochemistry, 1910.

HOPPE-SEYLER: *Zeit. fuer physiol. Chem.*, No. 9, *ibid* No. 19, 1894.

HOPKINS AND FLETCHER: *Jour. of Physiol.*, No. 35.

HORSLEY, V.: Mode of Death in Cerebral Compression, *Quarterly Journal*, London, 1894.

HEIDER: Chemical Pathology in Practice, 1910.

HUBBY: Observations on Blood Pressure in Intra-cranial Complications, etc. *Medical Review of Reviews*, Vol. 14, No. 1, 1908.

HUNTOON, F. W.: Studies in Meningitis. *Journal of Medical Research*, Vol. 20, No. 4 (New Series Vol. 15, No. 4, June, 1909).

IRISWA: Milchsaure in Blut und Harn. *Zeitschr. fuer Physiol. Chem.*, Vol. 17, 1893.

JAKOCH: *Quarterly Journal of Medicine*, Vol. 3, 1909-1910.

JANSEN: Internat. Med. Congress zu Moskau, Ref. *Arch. fuer Ohrenh*, No. 45; *Monatschr. fuer Ohrenh.*, 1897.

JOEL: *Deutch. Med. Wochnschr.*, No. 8, 1895.

KAPLAN, M. D.: Approximate Estimation of Protein (globulin) in Cerebrospinal Fluid. *N. Y. Med. Record*, Dec., 1910; also Neurological Seriology. *Journal of Nervous and Mental Diseases*, Vol. 38, No. 6, June, 1911.

KENDALL, ARTHUR: *Jour. Med. Research.* (Boston), Sept., 1911.

KOERNER: Die Eitrige Erkrankungen des Hirns, etc., 1902; also Nachtraege, published in 1908.

KOCHER: Hirnershuetterung, Hirndruck. Nothnagel's Spec. Path. und Therap. Bd. 9, Th. 3, Abd. 2.

KOPETZKY: Lumbar Puncture. *Amer. Jour. of the Medical Sciences*, April, 1906.

KUHN: Die Zuckerbehandlung der Brauchfellentzuendung. (Good bibliography.) *Arch. f. Klin. Chir.*, Bd. 96, 1911.

LANDSTEINER AND POPPER: *Zeit. fuer Immunitaetsforsch. orig.*, No. 2, 1909.

LANGENDORF: *Neural. Centralbl.*, No. 14, 1885; *Centralbl, f. d. Med. Wis.*, No. 25, 1886; (see, also, Miller and Ort, *Pflueger's Arch.*, Vol. CIII, 1904).

LEHNDORF, H.: *Zeit. Exp. Path. and Therap.*, No. 4, 1907.

LEYDEN: *Virchow's Arch.*, 1866, Bd. 37.

LEWIS AND FLEXNER: *Jour. A. M. A.*, No. 53, 1909.

LEWANDOWSKY: *Zeitschr. Klin. Med.*, Vol. 40, page 480.

LOCKERMANN AND FUETH: *Zeitschr. fuer Gynecolog.*, Jan. 13, 1906.

LOCKERMANN: Milchsaure in Blut und Cerebrospinal Fluessigkeit, bei Eklampie. *Muench. Med. Woch.*, 1906, No. 7.

LUCHSINGER AND SOKALOW: *Pfluegers' Arch.*, Bd. 23.

LYONS: *Arch. fuer Hygiene*, No. 30, Vol. 28, 1897.

MAYERHOFER: *Berl. Klin. Woch.*, May 5, Vol. 23, No. 18.

MERKENS: Ueber Intracranielle Complicationen der Mittelohreiterungen. *Deut. Zeit. fuer Chir.*, Bd. 60.

MIKULICZ: *Handbuch der Prakt. Chir.*, Vol. 1.

MOTT AND BARRETT: *Proc. Phys. Society, Jour. of Phys.*, Vol. 24.

MOTT AND HALLIBURTON: Chemistry of Nerve Degeneration. *Lancet*, April 13, 1901.

MOORE, B.: In Hill's Recent Advances in Physiology and Biochemistry.

MORANI: *Maly's Jahrber*, No. 9; *Heffler's Arch. f. Exp. Path. and Pharm.*, No. 31.

MUELLER, F.: *Mittheil. a. d. Wuerzburger Med. Klin.*, Vol. 1, p. 267.

NAEGLE: *Jahrber fuer Prak. Chem.*, Vol. 21.

NASHIMURA: *Arch. fuer Hygiene*, Vol. 18, 1893.

NAWRATCKI: *Zeitschr. f. Physiol. Chem.*, Vol. 23, 1897.

NOLL: *Zeitschr. fur Physiol. Chem.*, Vol. 27.

PANZER, TH.: *Wiener klin. Wchnschr.*, No. 31, 1899.

PETRUSCHKY: Ueber Stoffwechselproducte von Microorganen. *Zeitschr. fur Hygiene*, Bd. 12, 1892.

PORTER AND STORY: *Amer. Jour. of Phys.*, March, 1907.

POPPER AND LANDSTEINER: *Zeitschr. fuer Immunitatsforchung*, No. 2, 1909.

RAINY: *Jour. of Pathol.*, No. 6, 1900.

RANSOM: *Schmiegelow's Arch.*, No. 49, 1903.

RAVANT, SICARD AND WIDAL: *La Presse Medical*, Oct. 24, 1900.

ROBSON: *Mercredi Medical*, 1890, p. 418.

ROLLISTON: *Jour. of Physiol.*, Vol. 11, page 208.

ROSENFELD: Fettbildung Ergebnisse der Physiologie, 1902-1903.

ROY AND SHERRINGTON: *Jour. of Phys. London*, Vol. 11, 1890.

SALKOWSKI: *Allgem. Zeitschr. f. Pschiatrie*, Bd. 1, 59, Heft 5.

SAUERBACH: *Mitth. a. d. Grenz. d. Med. und Chir.*, Vol. 18, 1907.

SCHAEFER: *Allgem. Zeitschr. f. Pschiatrie*, Bd. 1, 59, Heft 5.

SCHMIEGELOW: *Zeitschr. fuer Ohr.*, Bd. 28, 1896.

V. SCHULTEN: *Arch. fuer klin. Chir.*, Bd. 32.

SELMI: Sulle ptomaine ed alcoloidi cadaverici e loro importanza in tossicologia. Bologne, 1876. Bericht. d. deut. Chem. Gesellsch, Vol. 2.

SHERRINGTON: *Jour. of Phys.*, London, Vol. 11, 1890, p. 85.

SICARD, RAVAND AND WIDAL: *La Presse Medicale*, Oct. 24, 1900; La liquide ophalo-rachidieme, Paris, 1902.

SLADEN, FRANK J.: *Johns Hopkins Hosp. Bull.*, Vol. 25, 1910.

SMITH, THEO.: *Trans. Amer. Physiol.*, 1896.

SOKOLOW AND LUCHSINGER: *Pfluegers' Arch.*, Bd. 23.

SOFFIAN, A.: *Jour. A. M. A.*, Vol. 58, No. 12.

STOCKUM: Sur la Compress. Cerebrele 7eme Congres di Chir. Paris.

SWAIN: *Zeitschr. fuer Ohrenh.*, No. 31.

TROTTER: Cheyne-Stokes Phenomenon in Acute Cerebral Compression. *Lancet*, 1907.

UNDERHILL: A Note on Presence of Lactic Acid in Urine of Pernicious Vomiting of Pregnancy. *Jour. of Biol. Chem.*, Vol. 2, 1907.

DI VESTEA AND ZAGARI: *Arch. f. l. Scienza mediche*, No. 9, 1887.

VERWORN: *Arch. fuer Anat. and Physiol*, 1900, p. 152.

WALDVOGEL: *Deut. Med. Wochnschr.*, 1898; Case 3.

WARREN: *Pfluegers' Arch.*, No. 24.

WIDAL, SICARD AND RAVANT: *La Presse Medicale*, Oct. 24, 1900.

YVON: *Jour. de Pharm. et de Chem.*, 4 series, 1877, Vol. 26.

ZANIER: *Centralbl. fuer Physiol.*, No. 10, 1896.

ZDAREK: *Zeitschr. fuer Physiol. Chem.*, Bd. 35, Heft 3.

ZIELLESEN: *Zeitschr. fuer Physiol. Chem.*, No. 15, 1891.

ZUCO: *Maly's Jahrber*, No. 24, pages 181 and 698.

ZWEIFEL: Das Gift der Eklampsie. *Muench med. Wchnschr.*, No. 7, 906, *Arch. fuer Gynecol.*, Bd. 72 and 76.

THE SURGICAL TREATMENT OF MENINGITIS, ITS SCOPE AND ACCOMPLISHMENT.

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Chapter I.—Introduction.

The term "meningitis" was introduced by an army surgeon, named Herpin,[1] in 1803. It indicates a septic process involving the membranes of the brain caused by various organisms. The mortality in meningitis varies from twenty per cent to one hundred per cent, depending upon the kind of infecting organism. Its lethal effects are due to three separate and yet inseparably intermingled factors, the poisonous effects of the toxins manufactured by the bacteria themselves, the toxins generated in the tissues and cerebrospinal fluid as a result of bacterial action upon them, and, to the mechanical effects of the pressure produced within the skull by the products of inflammation. *Septic conditions are usually surgical opportunities and demand surgical treatment.*

The treatment of suppuration within the meninges of the brain is not on a par with the treatment of sepsis elsewhere in the body. In most all other forms of septic infection, special or general, local or diffuse, surgery has secured a great diminution of mortality and a remarkable preservation of function. But, concerning meningitis, with the exception of the serous and diplococcic forms, its mortality is just as high as it was in 1870, before the dawn of craniospinal surgery, which since then in other lesions of the brain and cord has achieved such notable results.

I propose to review the records of the past forty years, to ascertain, if possible, the reasons for the present deplorable situation in the treatment of this disease and to show that there is hope for the future.

After correlating the experiences of the past, the opinions of the present and the latest results in practical and laboratory research, with a firm belief in the reason and justice of our contention, I desire to submit for critical examination and actual test a rational, safe and efficient surgical procedure for the treatment of meningitis.

Historical Review.

As a preliminary observation in regard to the operative treatment of intra-cranial suppuration the following quotation from a paper by Gross[2] is given; this was published in 1873:

"The treatment of compression of the brain from effusion of pus is purely surgical, and all authors are unanimous in the opinion that, unless the matter be evacuated, the patient will die, although they are equally agreed that this measure holds out but little chance of life."

A little farther he says: "No case is recorded of recovery from "effusion of pus into the arachnoid cavity," that one feels that he let out, * * * on the other hand, if a free incision be made into the dura mater so as to admit of its ready escape, one-half of the patients, as I have just shown, fight their way through. The necessity of operation is, therefore, not to be questioned."

While Gross referred to intra-cranial suppuration due primarily to traumatic causes, his statement is so explicit in reference to "effusion of pus into the arachnoid cavity," that one feels that he fully comprehended the necessity of surgical measures in all such cases of whatever origin, and their utter hopelessness when otherwise treated.

We go a long ways before we come to anyone else suggesting surgical intervention for "effusion of pus within the arachnoid cavity."

Ventricular puncture and drainage is the next deliberate procedure offered for the relief of the effusion in meningitis.

According to von Beck,[3] this conception was first expressed theoretically by Wernicke, in 1881.

Further that von Bergman was the first to use it in 1888, in a case of tubercular meningitis. He was closely followed by a number of operators, as Keen, Robson, Franks, Wyss, Hahn, Kocher and McCosh, in such cranial lesions as meningitis, brain tumors, and epilepsy.

Von Beck reports a case of "Acute Internal Hydrocephalus" following a chronic otitis media, in a boy of 14, in which the lateral ventricles were punctured at three different times, with the withdrawal of 26, 40, and 40 ccm. of cerebro-spinal fluid. The child recovered.

He also described a case of "A Traumatic Cerebral Abscess" in the frontal lobe that was incised and drained. This was followed by diffuse, purulent meningitis with acute internal hydrocephalus. Fifteen days after the first operation the lateral ventricle was punctured, 40 ccm. of turbid cerebro-spinal fluid drawn off. The boy, (7 years old), was moribund at the time of the last operation, but recovered after an illness of 126 days.

Quincke[4] describes a case of a child, 12 years old, with hydrocephalus, upon whom he performed ventricular puncture on June 25, 1888, because all other forms of treatment had been unavailing. The lateral ventricles were tapped at different points five times thereafter, but the child finally died from meningitis.

W. Mayo Robson[5] was among the first to conceive the idea of ventricular drainage in meningitis, and, while antedated in its execution by both von Bergman and Quincke, is entitled with them to receive credit for this operative suggestion. He writes:—"In 1888, while sitting powerless by the bed of a child dying of coma, due to meningitis, a train of thoughts passed through my mind, which culminated in the ideas set forth in this paper. If we have a serous, purulent or tuberculous peritonitis, we do not hesitate to open the abdomen and drain it; and if we have a plura full of fluid, we feel it our duty to perform paracentesis, or if the fluid be purulent, to incise and drain the chest. Then why do we allow the brain to suffer compression, even unto death, when we can, as the following case will prove, tap the ventricles and remove the pressure?" Here follows the report of a case, in which he operated on February 7, 1889, by puncturing the lateral ventricles through a trephine opening over the left motor area. Six ounces of clear fluid were removed. Recovery followed, without superficial suppuration, in a month.

The plan next suggested and executed for relief in meningitis, attacked the disease at an entirely different point, namely by draining the spinal subarachnoid space in the lumbar region.

To W. Essex Wynter[6] must be given the credit for the conception and first operation of spinal drainage in the treatment of meningitis. His first case was operated upon, February, 1889.

Of course, to Corning[7] belongs the honor of the first lumbar puncture, but this was for the injection of drugs, not for drainage of inflammatory exudation.

In his paper, Wynter says: "In many cases of fatal tubercular meningitis, coma supervenes with great rapidity and with all the signs of cerebral pressure, whilst after death little can be found except an excess of cerebro-spinal fluid, often at a considerable positive pressure, to account for the symptoms and the fatal issue. The possibility of recovery in this class of cases, where there is commonly little development of tubercle, together with the feasibility of draining away the fluid continuously by the theca vertebralis, suggested this mode of procedure."

His first case was a boy of 3 years of age in the comatose stage of tubercular meningitis. The operation did not require an anesthetic. The child was held in a sitting position. "A tiny incision was made in the skin beside the spine of the second lumbar vertebra and a Southey's tube and trocar inserted till the point impinged against the lamina; the point was then directed slightly downward and was pushed through the ligamentum and theca with

an inclination toward the middle line. Clear fluid at once welled up into the tube on withdrawing the trocar, a fine India rubber tube was arranged for continuous drainage and the child put back to bed." Although all the symptoms were immediately improved, the fluid ceased to flow after twenty-four hours and the child died.

Wynter's second case, operated upon February 21, 1890, was a lumbar laminectomy. Briefly, it as as follows: Girl, aged 11. Wynter cut down upon the second lumbar vertebra, removed the spine and right lamina and punctured the theca with a knife. Clear fluid escaped with force. A drainage tube was placed in the canal. Improvement in all symptoms followed immediately, but with the stoppage of the flow of fluid three days later, they became worse and the child died on the next day.

It was not until December 12, 1890, that Quincke[4] performed lumbar puncture according to a technic devised by himself and accepted and universally practiced ever since. It is due to his careful experiments and explicit directions for performing this operation that his claims for pioneer work in this field rests, because he was clearly antedated by Wynter by a year and ten months, in the actual performance of the operation.

Please note that Wynter's first case was a deliberate lumbar puncture with provision for continuous drainage, whereas his second case was a lumbar laminectomy with tube drainage. Quincke's first case had very marked hydrocephalus, with acute cerebro-spinal meningitis. A boy, 18 months old. Quincke did his first lumbar puncture December 12, 1890, between the third and fourth lumbar vertebrae and drew off a cubic centimeter of clear fluid. The puncture was repeated on December 14, with removal of 10 ccm. fluid in 20 or 30 minutes. Again on December 17, puncture below the fourth vertebra was done and the pressure of the cerebro-spinal fluid noted at 13 to 15 cm. of water, or 10 to 11 mm. Hg. When the child cried the pressure rose to 20 cm. of water but quickly dropped back to 15 cm. again. The flow was about 8 drops per minute. The child was convalescent by December 23, and fully recovered by January 10. Quincke considered this a lepto-meningitis infantum or simple acute hydrocephalus. He states in a footnote that the normal pressure of the cerebro-spinal fluid, with the child in a horizontal position was about 4 mm. of mercury.

The third case reported by Wynter was another laminectomy operation which was performed by Pierce Gould, on June 21, 1890. He cut down upon and divided the lamina of the first lumbar vertebra. The spinal canal was opened with a knife. A slight amount of fluid escaped, a drainage tube was inserted, the

symptoms improved for a short time but the patient died. (Boy, 2 years old).

A fourth case in Wynter's report was a girl of 13 months in convulsions, semi-conscious, head retracted. April 15, 1891, a Southey's tube was introduced into the spinal canal in the lumbar region. Death followed in a few hours. Wynter remarks: "Though none of these cases were ultimately successful, no harm in any one resulted from the interference. In some there was temporary relief of the symptoms and the necropsy in each case showed ample reason for the fatal termination, either in general tuberculosis or failure in maintaining the drainage. Further experience will, no doubt, enable a better selection of cases to be made, and the treatment to be carried out more effectually.

Charles A. Morton[8] published a paper in 1891, upon "The Pathology of Tuberculous Meningitis with Reference to its Treatment by Tapping the Subarachnoid Space of the Spinal Cord." He says: "In view of the recent procedures of tapping the subarachnoid space of the spinal cord in cases of tuberculous meningitis, the pathology of the disease derives quite a new importance. The prospect of relief by surgical intervention in these cases depends on the relation which increased intraventricular pressure bears to other pathological changes and to the symptoms, and whether, from the conditions found after death, there seems a fair chance of our being able to relieve this pressure by tapping the subarachnoid space of the spinal cord." Morton's statements are introduced here to show that at this time he was thinking of the possibility of drainage in tubercular meningitis.

Victor Horsley,[9] in December, 1890, in reference to the treatment of septic meningitis, proposed "Free drainage and disinfection, and the immediate consequences—relief." Further, "I have put down septic meningitis as a condition which might be improved by operation, such as free drainage and irrigation with warm disinfectants. I do not, however, believe that this course will always successfully rescue these otherwise hopeless cases. In fact, I have operated twice, once by way of exploration and once deliberately, but in both the moribund patients succumbed, after temporary though marked remission of their symptoms."

To Ballance[10] probably belongs the credit for first attacking meningitis by the occipital route. His statements made in 1897, "with regard to the operation of draining the posterior subarachnoid cistern, which had been described by Parkin in 1893, who had first performed it in 1891. The occipital bone was trephined close to the

foramen magnum. One case died of hemorrhage from opening an abnormal sinus, which was an accessory lateral one situated lower than usual. Some cases had been opened on both sides of the middle line so as to prevent hernia of the cerebellum interfering with drainage."

While Ballance was undoubtedly the first surgeon to deliberately drain the occipital fossa for septic meningitis, his work was not made public until six years later, and to Alfred Parkin,[11] who independently planned, executed and published the following operation, we should accord as much credit as if he had, in point of time, been the first to perform the operation. His case is as follows:

On April 9, 1893, Parkin operated upon a child 4½ years of age, who had been sick for a month with meningitis. At the time of the operation there was Cheney-Stokes respiration, swelling of the optic discs, transient rigidity of the limbs, unconsciousness almost amounting to coma. Pulse 150, and respirations 50. No anesthetic was required. "An incision was made below the superior curved line of the occipital bone and to the right of the middle line. The flap was reflected and a circle of bone, three-fourths of an inch in diameter removed and the opening enlarged in a downward direction. The dura bulged very much, no pulsation was felt. It was opened and a little fluid escaped. On passing a curved probe along the under surface of the cerebellum and raising it slightly a very large quantity of clear cerebro-spinal fluid (about two or three ounces), gushed out; pressure was relieved and the brain pulsation returned. The Cheney-Stokes rhythm ceased and the pulse became larger and regular, though still very quick. A very fine, almost capillary drainage tube was inserted beneath the dura mater and both it and the scalp wound were sewn up." In spite of free drainage up to the last, the child died sixteen hours later. Necropsy showed generalized tuberculosis of lungs, liver and meninges.

In this connection I wish to refer again to the work of Morton,[12] whose operation for subarachnoid drainage has been referred to by later writers who give an erroneous idea of what Morton really intended to accomplish.

In order to make the matter clear, I will quote from Morton's papers on "The Opening Between the Fourth Ventricle and Subarachnoid Space and its Condition in Tuberculous Meningitis," and the "Best Point for Direct Drainage of the Ventricles."

Morton states that in 1891 he gave a paper on the pathology of tubercular meningitis, to which reference has already been made with regard to its treatment by tapping the subarachnoid space of

the cord. Since then he has investigated the condition of the opening from the fourth ventricle into the posterior subarachnoid space, in seven normal and seven cases of tubercular meningitis. It is evident that if the foramen of Magendie be closed, drainage of the ventricles of the brain by tapping the subarachnoid space is impossible. His examinations show that the foramen is never closed.

"Morton's method" for exposing the foramen of Magendie so as not to disturb its condition or relations consisted in first removing the skull-cap, the section being carried low down behind. Then a wedge-shaped piece is removed from the middle of the occipital bone, with its base uppermost and with the apex, almost an inch wide, forming the upper boundary of the foramen magnum. The removal of this wedge exposes the dura which is incised, the arachnoid is exposed and also incised. The fluid is gently sucked up with a sponge. "In this method there is no possibility of rupture of the pia mater closing in the ventricle."

In reference to the second point in his paper, "the drainage of the ventricles," he advises that they be drained "through a trephine opening, situated one and one-fourth to one and one-half inch behind and the same distance above the external meatus."

"Morton's method" then, in so far as it referred to the posterior subarachnoid space, was a method of exposing the foramen of Magendie, *post mortem* so as not to disturb its condition or relations. It had nothing to do with drainage of this space except to show that the foramen of Magendie was never closed. Therefore this space could be drained by way of the spinal subarachnoid space (already demonstrated by Wynter and Quincke), or through the lateral ventricles (previously advocated and performed by Bergmann and others).

Ord and Waterhouse [13] reported the recovery of a girl, 5 years of age, who was nearly moribund with "tubercular meningitis with increased intra-cranial pressure, the stage of coma rapidly advancing and unless pressure was relieved, a fatal termination seemed inevitable." The operation was done under chloroform, October 26, 1893. "A curved incision, two-and-a-half inches long, over the left cerebellar fossa of the occipital bone, commencing below and behind the mastoid process, passing with its convexity upward and ending externally to the external occipital crest. Furious bleeding from the occipital artery. Some bleeding from a torn mastoid vein. Pericranium raised in a flap similar to the scalp flap. A three-quarter of an inch trephine hole was made midway between the external occipital crest and the mastoid process. The dura bulged tensely

into the opening, there were no pulsations. The dura and the arachnoid were incised and some thirty drops of a slightly greenish serous fluid escaped. The cerebellum bulged into the trephine opening, fitting it tightly like a cork in a bottle. A probe was passed between the cerebellum and the arachnoid towards the falx cerebelli and some drachms of fluid escaped. A drainage tube was passed along the probe and left in position. Fluid slowly passed along it. The dura was sutured, the fragmented bone-button packed in the opening and the flap sutured with the drainage tube escaping through a stab-hole in its middle. Drainage continued until the end of the following month when recovery was complete."

In this connection we should note that Fischer[14] refers to a case sent by Browning, of Brooklyn, to the Bushwick Hospital, in which an operation was performed at the occipital site.

After disappointments became numerous in the use of lumbar puncture as a therapeutical measure in meningitis, the introduction of various drugs into the subarachnoid space was attempted. Thus Rolgaus,[15] in two cases of tubercular meningitis, injected into the "subdural" (?) cavity an emulsion of iodoform, but without result. Next Sokolov,[16] reflecting upon the similarity between tubercular peritonitis and meningitis and, being familiar with the curative action of merely exposing the viscera to the atmospheric air in the former, attempted to carry out the analogy in the treatment of this form of meningitis. He trephined, aspirated the cerebro-spinal fluid through a lumbar puncture and then insufflated air into the subarachnoid space through the lumbar puncture. He did not state the results of this treatment.

A combination of craniotomy and lumbar puncture was performed by Gradenigo[17] in three cases of suppurative otitic leptomeningitis, with recovery in all.

Chipault,[18] in 1894, advocated opening the "Sylvian lake" for drainage purposes in chronic hydrocephalus and tubercular meningitis.

Witzel,[19] in September, 1897, operated upon a boy, 16 years old, who had a circumscribed phlegmonous meningitis following right ear disease, by widely removing the squamous portion of the temporal bone and introducing gauze drainage after ventricular puncture had been negative. The patient died after four months of illness, with generalized meningitis. He also reports a second case of fracture of the base of the skull, followed by basilar meningitis, that was cured by the temporal operation.

In January, 1899, Rolleson and Allingham[20] treated a case of cerebro-spinal meningitis in a man, 24 years of age, by performing a laminectomy of the seventh and eighth dorsal vertebrae. Drainage was provided by a rubber tube which was removed on the ninth day. The patient recovered. They remark, "as far as we can find out the spinal dura has not been freely opened before in acute cerebro-spinal meningitis." Evidently they did not know of Wynter's case.

When we come to consider cerebro-spinal meningitis due to the extension from purulent foci within the skull, the rôle that suppurative ear disease plays is a very important one, and, while a consideration of this special aspect of the subject is foreign, at this time, to our purpose, yet to make the review more complete, these cases are introduced here.

To Macewen[21] we unhesitatingly give the credit for pioneer planning and operating in this class of meningeal inflammation. He gives a summary of twelve cases of infective, purulent lepto-meningitis, of which six were operated upon and recovered. Five of these were of the cerebral fossa and one of the cerebellar fossa. Six other cases, considered hopeless for operation, died. Of six other cases of cerebro-spinal lepto-meningitis, five were operated upon with one recovery.

Hinsberg[22] reported seven cures and five temporary improvements in meningitis of otitic origin, after drainage of the subarachnoid cavity.

In otological literature there are numerous similar cases on record in which a craniotomy in connection with the operation upon the diseased ear was performed to reach and drain a circumscribed or general purulent meningitis. Lumbar puncture, as above noted, has been used for purposes of diagnosis and a possible therapeutic effect.

Friedrich,[23] in cases of cerebro-spinal meningitis of otitic origin, advocated incision of the dura at the site of the infection and in addition performing a laminectomy. Held and Kopetzky[24] give the details of a remarkable case of purulent meningitis following a double otitis media in which pus was obtained from the subarachnoid space in the temporal region, through the enlarged mastoid wound, from the spinal space by lumbar puncture and from the lateral ventricle through puncture. The girl, 3 years of age, finally recovered after this widely disseminated infection in which were found steptococci and staphylococci, the latter predominating.

Kuemmel's[25] case, frequently quoted, is introduced here to fur-

ther emphasize the possibility of recovery from a purulent meningitis after a double trephining of the occipital bone and the institution of drainage.

The patient was a man of 33 years, who sustained a fracture at the base of the skull. Lumbar puncture drew off 20 ccm. of purulent fluid under a pressure of 235 mm. of mercury without relief. After the occipital operation the patient began to improve and fully recovered in six weeks.

In 1906, Widal and Ramond[26] treated a case of cerebro-spinal meningitis by injecting through a lumbar puncture 5 cm. of a 1-100 solution of collargol in water. This was repeated a second time on the twenty-ninth day and the patient discharged cured on the thirty-sixth.

In April, 1907, the anti-meningitis serum, prepared at the Rockefeller Institute under the direction of Flexner, was used for the first time in treating epidemic cerebro-spinal meningitis in human beings, by Ladd, of Cleveland (Dunn[27]). This serum was introduced through a lumbar puncture made in the usual way.

Radman,[28] in writing upon the surgical treatment of epidemic meningitis, advocates drainage of the fourth ventricle by an incision through the atlanto-occipital ligament. Fischer[29] reports a case of cerebro-spinal meningitis in an infant, 2 months old, in which recovery seemed to follow repeated irrigation of the lateral ventricles with a normal saline solution, combined with several lumbar punctures. Pollack,[30] among some other cerebral lesions, recommends puncture of the brain in hydrocephalus after his method of introducing the needle through a small drill-hole in the skull. Bramann[31] has treated eighteen cases of hydrocephalus by puncture of the corpus callosum. Brem and Zeiler[32] suggest the treatment of influenzal meningitis by permanent spinal drainage combined with the internal administration of hexamethylenamin.

Chapter II.—Anatomy and Physiology.

It is assumed that the reader is familiar with the fundamentals of brain and cord anatomy and physiology. Some parts, however, which are especially concerned in the problems before us, must be emphasized.

THE ANATOMY.

The Cerebro-spinal Cavity:—The cerebro-spinal space in the natural condition is a closed cavity, limited by bones and firm ligaments. It is incapable of expansion or distention except in the infant with open fontenelles and then only to a very slight amount.

The Brain and Cord:—The brain consists of two symmetrical hemispheres which are united over a restricted portion of their opposed surfaces by the wide collosal commissure above and the basal structures below. From the base of the brain fibers emerge, crowded together to form the crura cerebri and passing downward to become the pons, medulla and spinal cord. The cerebellum, beneath the hinder portion of the cerebrum and behind the pons and medulla is united to these parts by masses of fiber. All these last parts together constitute the brain.

The Ventricles of the Brain:—Within the substance of the cerebral hemispheres lies the spaces called the lateral ventricles, while between the hemispheres is another space, the third ventricle. The cavity of the former spaces is continued into that of the latter by two semilunar slit-like openings, the foramina of Monro. Between the cerebellum, pons and medulla lies another wide space, the fourth ventricle, which is united to the third ventricle by the aqueduct of Sylvius, a narrow tunnel through the hinder part of the cerebral crura.

While the cavity of the fourth ventricle is mostly walled in by the substance of the cerebellum, pons and medulla its posterior wall or "roof" is furnished by the pia lined by a thin membrane (representing the attenuated roof of the primitive brain), and termed the tela choroidea inferior. This "roof" is incomplete in its central portion near the lower part of the fourth ventricle, where an opening is found—the foramen of Magendie—by which communication is established between these spaecs within the brain and those (to be subsequently mentioned) without. Further, narrow gaps are found in the lateral angles of the fourth ventricle which also open into the spaces without the brain. These are the foramina of Luschka, or Key, and of Retzius. In passing, we should mention that the fourth ventricle is continued throughout the spinal cord as a small central canal.

The Membranes of the Brain:—The dura. This is a dense membrane lining the interior of the skull—forming its internal periosteum —also extending to the bottom of the spinal canal—but not acting as a periosteum for the vertebrae. It smooths out inequalities of the cranium and effectually blocks up all points of exit therefrom. From the dura are derived two large incomplete diaphragms, the tentorium cerebelli and the falx cerebri. The former aids in forming a chamber within which lie the cerebellum, pons and medulla: the latter is suspended between the cerebral hemispheres. Along the margins of attachment of these partitions to the skull, and to

each other and within the separated layers composing them are found large channels—the cranial sinuses—by which the venous blood is removed from the brain.

The Sinuses:—The cranial sinuses which enter at all into our consideration are the superior longitudinal, straight, lateral and occipital. The superior longitudinal sinus is especially important, not merely because of its size, but because of the connection with it of broad, irregular venous spaces called the parasinoidal sinuses or the lacunae laterales. These lateral lakes vary in width from one-half to one inch and into them, as well as into the sinus itself, open the cerebral veins and project the Pacchionian bodies (see latter).

The straight sinus receives the venous blood from the interior of the brain through the veins of Galen and opens, with the superior longitudinal into the confluence of sinuses from which pass off the lateral sinuses to the base of the skull where they are continuous with the internal jugular veins.

The occipital sinus is usually a small one in the falx cerebelli; it may be wanting entirely, may be double, and rarely may be of considerable size. It opens into the torcular above and near the margin of the foramen magnum bifurcates into two smaller venous tracts—the marginal sinuses—which course around the border of the foramen and empty into the lateral sinuses near their termination.

The Intradural or Subdural Space:—This is the very narrow interval left between the dura and the next membrane—arachnoid—it is a potential rather than a real "space" and harbors a very little cerebro-spinal fluid for purposes of promoting freedom of motion between the brain and the skull.

The Pia:—Immediately applied to the brain and the cord is the pia. A layer composed of blood-vessels with only enough connective tissue to hold them in place. The pia follows all the irregularities of the surface of the brain, dipping into all the sulci and, further, projecting into the ventricular cavities as masses of capillary festoons—the choroid plexuses of the various ventricles. A word further about these vascular plexuses. While they seem to lie free within the ventricles, in reality they are excluded from these spaces by a layer of epithelium which represents the thinned-out wall of the primitive cerebral vesicles. This construction is important to remember when we come to take up the physiology of these structures.

Besides these vascular plexuses there are other capillary tufts—the Pacchionian bodies—outgrowths from the pia which look like small masses of granulation-tissue and consist of a spongy trabecular network covered by a membrane continuous with the arachnoid. They project through the inner layer of the dura into the superior longitudinal sinus and the lateral lakes; also, they are found in fewer numbers along the upper surface of the superior vermis of the cerebellum. The Pacchionian bodies, before the age of three years, are wanting or very small and rudimentary. From the age of ten and onward they increase in number and size.

The Arachnoid:—This is a delicate membrane interposed between the dura and pia but so intimately connected with the latter as to seem on casual examination a part of it, especially over the convexity of the brain. However, at the various sulci the arachnoid and pia are seen to be separated, for while the pia dips into the sulci the arachnoid bridges them over. It is at the base of the brain that the existence of two layers is most easily demonstrated. Here, while the pia closely follows all the irregularities of the parts, the arachnoid spreads from one elevation to another as a well-defined sheet. The spaces which are thus left between the pia and the arachnoid are narrow channels, over the convexity of the brain; but at the base they are large spaces, and are given localizing names as cisterna basilis, cisterna pontis and cisterna cerebello-medullaris or magna. These spaces communicate with each other in the freest manner possible; also, with the narrow channels over the convexity of the brain, and especially, at the cisterna magna not only with the wide subarachnoid space of the spinal canal but also with the fourth ventricle through the foramen of Magendie and the lateral foramina of Key and Retzius.

While there is more or less of a spongy tissue connecting the arachnoid with the pia over the convexity of the brain, still, as Cunningham[33] says: "In these (cisternae) there is no longer a close network; the trabeculae connecting the two membranes take the form of long filamentous, intersecting threads which traverse the spaces."

In this connection the attention of the reader is called to the foramen of Magendie. The text-books give no description of this opening that would enable one to form any conception of its shape or size; therefore I shall quote the correct picture given by Morton,[12] which also expresses my own conclusions in this particular.

"The opening is not accurately described as a foramen, in the sense of a small hole in the pia mater. The opening in the nor-

mal brain reaches from the cerebellum to the calamus scriptorius below, and is a broad slit or a larger space. Sometimes a few delicate strands of membrane intersect one another across it but this is only occasionally seen."

Further, Lees[24] states that it is larger in infants than in the adult. Anatomically, there is no direct connection between the subdural, or better, the intradural space, and the subarachnoid or intra-arachnoid spaces, but the arachnoid tissue is so porous that, anatomically, physiologically and pathologically the intradural space may be considered as identical with the subarachnoid spaces.

The Blood Vessels:—The internal carotids and vertebrals furnish arterial blood to the base of the brain, which, through the mechanical construction of the circle of Willis is adequately distributed to the entire brain, both externally and internally. It is sufficient for our purpose to state that from the arteries, capillaries are formed, which again converging, unite to form gradually the various intra- and extra-cerebral veins. The former are chiefly gathered up into the main trunks of the veins of Galen and these two empty into the straight sinus. The external veins course mostly over the convexity of the cerebrum and end in the superior longitudinal sinus or the lateral lakes opening into it. There are other venous connections with the sinuses, with each other, and with the veins of the diploe which we can disregard at this time.

The Lymphatics:—(Macewen,[21] page 38). "The lymphatics of the dura are abundant. There is besides, a wide-meshed capillary network with peculiar dilitations near the inner surface of the cranial dura. * * * The subdural space communicates with the lymphatics in the dura, while the latter communicate with the dural veins. The intra-cranial lymphatics have their origin in the cerebral pia mater and in the choroid plexuses. They pass out of the cranial cavity along with the internal carotid and vertebral arteries and the internal jugular vein to the deep cervical glands. Others pass from the choroid plexuses of the lateral and third ventricles, coalescing into a lymphatic vessel which accompanies the veins of Galen."

Physiology:—The chief facts of interest to us respecting the circulation of the blood within the skull is that by various mechanical means the intermittent arterial flow is converted into a constant, steady stream. The details of this mechanism are well given by Macewen[21] (page 35), but do not require elaboration here. We, also, should note that there is always a positive pressure in the cranial sinuses, amounting to a few millimeter of mercury. (Bal-

lance.[35]) Of more importance to us is the cerebro-spinal fluid and its functions.

The cerebro-spinal fluid is secreted chiefly by the various choroidal plexuses. The current sets from the lateral ventricles through the foramina of Monro into the third ventricle and thence by the aqueduct of Sylvius into the fourth ventricle and from here it freely escapes into the cisterna magna and pontis through the large foramen of Magendie and the smaller foramina of Key and Retzius. From the cisterna magna the fluid passes slightly into the subarachnoid space of the spinal cord but mostly streams upward through the other cisterns and over the convexity of the brain into the cerebral veins and sinuses. "This direct passage of the cerebro-spinal fluid into the veins is one of the best established facts in the physiology of cerebral circulation, especially by way of the Pacchionian bodies" (Archibald[36]).

The pressure of the cerebro-spinal fluid in the subarachnoid spaces always exceeds by a few millimeters of mercury the cerebral venous pressure; therefore the flow of fluid is from the subarachnoid space into the venous system. As the specific gravity of the cerebro-spinal fluid is less than that of the blood, any flow determined by osmosis would be, in the main, in the same direction. (Ballance).

The quantity of the cerebro-spinal fluid varies with sex and age and never exceeds 200 ccm. (Gray[37]), or 60 to 80 ccm. (Howell[38]). It may, however, under the stimulation of injury and disease, be secreted in immense quantities. Giss[39] reports a loss of 30 liters in 37 days. Thompson, (quoted by Archibald), a loss of 500 ccm. in 24 hours.

Another function of the cerebro-spinal fluid is to form a "hydraulic buffer" (Ballance) between the cranium and the brain. As to its action in "supporting the weight of the brain" this is very slight, if any. Any one who has made and studied sections of the head and neck and the relations of the brain and cord to the surrounding parts will agree with Ballance that "the weight of the brain is not wholly, or even to any considerable extent supported by hydrostatic pressure."

The function of the Pacchionian bodies is so interesting and important in this study, that further notice is taken of it. Kocher[40] states it as follows:

With the expansion of the arteries at the base of the brain at each systole of the heart, the Pacchionian bodies and the cerebral

veins are compressed and empty their contained cerebro-spinal fluid through the thin layer of the dura into the sinuses. This current is also aided, during the diastole of the heart, when the arteries again contract, by the expansion of the Pacchionian bodies aspirating the cerebro-spinal fluid from the subdural and subarachnoid spaces. The cerebro-spinal fluid does not leave the skull by the lymphatics unless there is venous obstruction raising the pressure within the sinuses. (Archibald).

The chief function, then, of the cerebro-spinal fluid is to maintain at a constant level the intra-cranial pressure, which tends to vary with cardiac action, respiratory rhythm and changes in bodily position.

In infants, until the closure of the fontenelles and while the Pacchionian bodies are rudimentary and their function unimportant, the normal intra-cranial pressure is maintained and the circulation of the cerebro-spinal fluid assisted by the alternate expansion and retraction of the fontenelles with arterial pulsation and respiratory movement.

Chapter III.—Operative Treatment of Meningitis.

A. Foreword. B. Critical Review of Past Operations. C. Symptoms Which Furnish a Guide for Operation. D. What May an Operation Promise? E. When Should Operation be Undertaken? (a) To Save Life; (b) To Prevent Complications. F. Where Should the Operation be Performed?

A. *Foreword.*:—The historical review just given, while not exhaustive, is sufficiently comprehensive to give us a correct picture of meningitis treated by surgical measures. There is yet no medical treatment for this disease. What a picture it is of hopelessness, despair and death! The only ray of light cast on this dark field is given by the serum treatment of one particular form of this disease. But the mortality remaining after the use of this remedy is still sufficiently appalling, that were it in any other disease, it would fill us with consternation. While, in the other types of the disease death is the universal outcome. We have come to accept meningitis as a fatal disease. The facts of the past justify this conclusion. If, perchance, recovery did occur, how often would death have been preferable. A recovery with reason dethroned or weakened, with epileptic fits or other deplorable nerve lesions was more to be regretted than death. Is there, then, no hope? Must we fold our hands and let these patients die under stress of the greatest suffering?

We claim there is hope. We claim that if this disease is treated with common sense along lines of ordinary surgical technic used in other suppurative conditions, a fair percentage of these otherwise hopeless cases will recover.

What are the facts in the case? 1. That medical treatment is unavailing. 2. That surgical aid in every case reported has been deferred until the patients were moribund.

Ante-mortem surgery has never given, and can never give "good results." When the dictum is accepted in meningitis, as it is in appendicitis, mastoiditis and other suppurative diseases, that the only treatment is surgery, and that utilized at the earliest possible moment after the diagnosis is made, then, and only then, will the high mortality statistics of meningitis begin to fall.

The same fight is on here that was waged by surgeons with their medical confreres in the past over similar forms of suppurative disease. Take appendicitis. We know the steps in that contest. 1. Medical measures alone; 2. operating in moribund cases; 3. in abscess cases; 4. in the acute attack, before sepsis has had a chance to do any damage; 5. in the interval. How much fine hair-splitting was indulged in, in the past, as to when a case of appendicitis ceased to be a medical and became a surgical one.

What protests went up when Deaver announced, and adhered to it, that appendicitis is always a surgical condition and demands surgical treatment just as soon as the diagnosis is made.

Other similar affections, now relinquished to the surgeon, without a question, have had to go through the same cycle of evolution, and, I suppose, meningitis will prove no exception.

3. While admitting the futility of medical treatment and the desirability of surgical interference in the past, there has been no concerted action among surgeons themselves to develop an operation that would commend itself as reasonable, safe, and curative. The operations suggested and performed have had to do with some particular form of the disease and at the terminal stage of its course. Furthermore, they have been futile if simple, or so severe in their technic as to be contra-indicated.

4. The indications as to the proper time for surgical interference have not been clearly formulated. This has been due to the uncertainties of a positive diagnosis at an early stage in the disease; also, to the confusion arising from the multiplicity of types of meningitis, each one described as an entity based upon its etiology and post-mortem findings and none of them considered from the standpoint of possible surgical opportunities.

B. CRITICAL REVIEW OF PAST OPERATIONS.

Ventricular Puncture:—Ventricular puncture after the method of Kocher, Keen[41] or Pollock, through the cerebral cortex, or of Bramann, through the corpus callosum, is a procedure only to be utilized in cases of chronic hydrocephalus or in non-pyogenic serous effusions of the brain.

"In infected cases with a beginning external meningitis there is always a certain risk of innoculating an uninfected ventricle." Cushing.[42] In addition there is a real danger in infecting the cerebral cortex and more especially the meninges. Further, hemorrhage from a cerebral vein or from an injury to the choroid plexus is a not unlikely possibility. If ventricular puncture is performed for the purpose of draining a purulent effusion at the base of the brain, one only has to consider the anatomy of the parts involved to perceive at once the futility of such a procedure. Bruce Clark[43] states that he does not "think it possible to relieve purulent basic meningitis by tapping the ventricles." That the operation in itself is a serious one is conceded by all. Frazier[44] says, "puncture of the ventricles (lateral) is unfortunately an operation of unusual gravity and the danger attending it is so great in comparison to the possible benefit as to make it a procedure of questionable propriety." If that is true of the operation in non-infected conditions, how much more is it objectionable in septic effusions at the base of the brain to which is added the severe constitutional effects of such disease.

It is plain then, that ventricular puncture, as a therapeutic measure in the treatment of meningitis has no logical or clinical justification. It cannot drain pus. It may not relieve pressure. It adds a positive danger of infection of ventricles, cortex and meninges. Troublesome hemorrhage may be produced. The operation is a very serious one.

Lumbar Puncture:—The value of lumbar puncture lies in the positive diagnostic findings furnished by the cerebro-spinal fluid withdrawn by the puncture. As a means of diagnosis then, it is invaluable.

As a therapeutic measure it is inefficient except in the single condition of serous, non-purulent, meningitis. In all purulent conditions it has no curative powers. At its best, in epidemic cerebro-spinal meningitis lumbar puncture has a mortality of 66.6 per cent (Sladen[45]) in cases treated at the Johns Hopkins Hospital, before the introduction of the anti-meningococcus serum. In the frankly purulent infections lumbar puncture never cures. Archibald says

in reference to it, "that value of lumbar puncture is therefore definitely proved to be minimal," also that, "lumbar puncture, while of temporary value, fails to save life;" further, "if a block has occurred at the foramen, magnum lumbar puncture only adds to its intensity" and "in ventricular obstruction lumbar puncture ceases to be helpful." Cushing also warns against the danger of too quickly withdrawing the column of cerebro-spinal fluid and causing a plugging of the foramen magnum by the brain stem. Frasier says, "the sudden disturbance of pressure is no doubt responsible for a large majority of the fatalities. * * * Furbinger, who is very much opposed to this practice, attributes the deaths to pressure exerted upon the bulb by the arrest of cerebro-spinal fluid from the ventricles at the foramen of Magendie."

Lumbar puncture then, as a therapeutic agent, is a failure. It possesses elements of danger, when repeatedly used, which disqualify it. Not only does it fail to reduce mortality, but its repeated use is attended with grave complications.

Lumbar Puncture in Combination:—(a) With craniotomy for through and through irrigation; (b) for the injection of various curative agents (except serum) into the spinal canal has been tried and discarded as "impossible of performance" (Cushing) and incapable of curing the disease and positively dangerous. The single case of recovery after the injection of collargol was a type of serous meningitis in which recovery might have followed the puncture alone.

Laminectomy:—There is more to be said in its favor as a curative measure than for lumbar puncture. Yet the danger of "corking up the foramen magnum by the brain stem," the failure to secure adequate and sustained drainage, the severity of the operation itself all weigh against it, if there is any other proposition which will attain the desired ends without these drawbacks.

Serum Therapy:—This is limited to the treatment of cerebro-spinal fever caused by the diplococcus intracellularis of Weichselbaum. (Flexner[46]). It affects no other form of meningitis. In its particular field it has lowered a previous mortality of 72 to 95 per cent down to from 20 to 43 per cent (De Meric[47]) or of a mortality of 66.6 per cent to 17.4 per cent. (Sladen).

There is no longer any question but that Flexner's serum is a potent agent in reducing the mortality of epidemic meningitis from a previous figure of about 75 per cent down to one around 25 per cent. The beneficial effects of the serum are more manifest if

given before the fourth day of the disease and between the ages of 2 to 10 years. If given later than the fourth day or to patients younger than two years, or older than ten, the mortality rate quickly rises.

In all other forms of infection the serum has no curative action whatever. At the best then, in a series of selected cases, (time and age most favorable), the mortality rate is 13.1 per cent while the highest is 43 per cent. (Dunn).

The average we can take at 25 per cent, (it is above this*). What is to be done regarding this remaining fourth of epidemic meningitis cases and practically the total number of other forms of infectious meningitis?

While we believe in and advocate the use of the serum in the diplococcic form of meningitis, it must be remembered that there will be failures in its use amounting, as shown, from 10 per cent to 25 per cent of the cases. In addition, the serum in itself is not altogether harmless as shown by the cases reported by Hutinel,[48] four in number, in which death followed the second injection of the antiméningococcic serum. The danger of death is greater should the infection be the tubercular bacillus.

Ryfkogel[49] reported a case of coccidioidal meningitis in which death followed a second injection of the Flexner's serum. Netter, Courtois-Suffit and Dubosc[50] advise caution in the use of the serum, in too large doses or too frequently repeated.

The remaining varieties of cranial operations will be discussed in connection with the operative procedure suggested in this paper.

C. SYMPTOMS WHICH FURNISH A GUIDE FOR OPERATION.

The subject of meningitis is obscured by describing as separate entities various forms of meningeal inflammation. From an etiological and pathological standpoint, this is correct. But from a surgical point of view, such multiplicity of types only confuses the observer and serves no helpful purpose. He looses sight of these fundamental facts:—

*Sophian's[52] latest figures based upon the serum treatment of meningitis in the late Texas epidemic give the general mortality as 25 per cent in a total of 185 cases. "Excluding the apparently hopeless cases in which the patients died in from a few minutes to twenty-four hours after admission, the mortality was about 10 per cent. In children the mortality after the exclusion of apparently hopeless cases was roughly about 5 or 6 per cent." This again gives the very best showing for the serum therapy after all the "hopeless" cases have been weeded out. As soon as one starts this weeding-out process you can get almost any kind of mortality statistics.

NOTE:—No attempt has been made to ascertain all the disadvantages and dangers attending the use of the serum. We have given it all the credit claimed by its advocates and merely cite the above to show that its use may not only fail to do good in meningococcic meningitis but also may prove dangerous in this and other forms.

1. That all forms of meningitis are essentially septic in nature except the toxic, and this may become septic.

2. That all forms of meningitis kill, some only 10 per cent, others 100 per cent.

3. That death is caused in the last analysis by increased intra-cranial pressure progressing to such a point as to finally shut the blood off from the "vital centers."

4. That death can only be averted by furnishing good blood to the "vital centers" by *removal* of the intra-cranial pressure. Other appropriate and secondary measures will contribute to but cannot take the place of this paramount requirement. Irrespective, then, of the particular type of meningitis, of what has or has not been done before for therapeutic purposes, the indication for surgical action rest upon an unfailing chain of symptoms that, in practice at the bedside, can be absolutely determined with accuracy. (See Part I, by Dr. Kopetzky).

These early symptoms are: 1. A rising blood-pressure; determined by the cardiac sphygmomanometer. 2. Edema of papillae. (Not "choked disc," which is so late a symptom that it ceases to have any value). 3. Absence of carbo-hydrates from the cerebro-spinal fluid. (Obtained by lumbar puncture). 4. An irritable or clouding sensorium.

In addition, there may be present: A vagus pulse; respirations, irregular in depth and rate.

With these pathognomonic symptoms present, no possible consideration can justify delay.

The nearer a patient is to bulbar paralysis the less likely that any operation will save life. Recovery from such compression may not be at all or slowly. (ARCHIBALD.)

D. WHAT MAY AN OPERATION PROMISE.

While we concede that lumbar puncture may be all that is necessary in toxic meningitis, that by serum therapy epidemic meningitis has been rendered two-thirds less fatal than formerly, yet, for the remaining fourth of those sick with this form of meningitis and for all other forms of septic meningitis, death is the inevitable outcome.

NOTE:—The facts of cerebral compression as determined by experiment and shown in disease of the meninges have been given in detail by my co-worker on this subject, Dr. Kopetzky; (see part I). I should like to state, however, that we have repeated the experiments of Cushing in producing intra-cranial pressure, have demonstrated the accuracy of his observations, and the correctness of his conclusions, and, in addition, have produced in dogs, acute, septic meningitis and recorded the various changes resulting from such infection as observed through a glass window in the skull and by other methods of reducing physical phenomena to graphic record. The results of our experimental work demonstrates that intra-cranial pressure is the important feature of meningeal inflammation.

Further, while surgical procedures of the past have saved but a lamentably few cases, yet we must remember that surgery has invariably been resorted to as a last hope; that the patients were in the terminal stages of cerebral compression and also suffering from profound systemic poisoning, and that, as a rule, the operations performed upon the skull at a distance from or near to the seat of the trouble have all been, in themselves, of a very severe character.

We can readily understand, then, why surgery has thus far been unable to show any considerable number of victories.

CAN SURGERY RELIEVE THE COMPRESSION?

The evidence furnished by all cases operated upon show conclusively that pressure has been relieved—at least for the moment. Why, then, has death so invariably followed? 1. Because such relief has not been furnished at an early stage. 2. Because such relief has not been of sufficiently long duration. 3. Because, in addition to the evil effects of compression of the brain, constitutional septic conditions existed that continued to act after operative relief to cause death. 4. Because the meningeal infection had become so diffused and the products of such infection so organized as to make it impossible for Nature to further resist the progress of the disease or remove the effects of the inflammation.

All evidence warrants the conclusion that surgery has relieved all cases and has saved some. And it has succeeded in doing this in spite of the operation being performed at the very last, usually at some place unrelated to the seat of the disease and more frequently by a method of unnecessary severity of execution.

E. WHEN SHOULD OPERATION BE UNDERTAKEN?

a. *To Save Life*:—All the evidence, experimental ante- and post-mortem show conclusively that an early operation is absolutely necessary. Kocher advises operation in every case of cerebral lesion when there is only a *suspicion of pressure*. "It can no longer be doubted that in some cases of suppurative meningitis recovery may be brought about by active intervention. We are no longer justified in regarding such cases as hopelessly lost, and in remaining with folded hands. Rather must we attempt to save them by doing the utmost within our power." Hinsberg.[51]

"The reproach of such a death rate (in septic meningitis) will not be removed by refusal to operate, but by an early and universal recognition of the futility of the treatment by drugs" (Horsley). "All forms of meningitis, if unrelieved by art, tend to cause death." (Ballance).

The otologists as a class have recognized the importance of early operations in septic meningitis of otitic origin. Their teaching is to follow up the disease until all parts affected have been brought into the field of surgical relief. (Kopetzky.)

b. *To Prevent Complications*:—In serum treated cases complications attributable to the disease (epidemic cerebro-spinal meningitis) arose in 43.5 per cent. In non-serum cases these were 63.6 per cent of about the same character. (Sladen).

"Early recognition, followed by operation, have in certain cases checked the disease (infective meningitis), and as our experience ripens concerning them, the results will doubtless be improved." (Macewen).

"Energetic prophylactic decompression would reduce to a minimum such disastrous results as optic neuritis, deafness, oculo-motor disturbances, and some psychopathies, all of which are due to the mechanical effects of the excessive intra-cranial pressure." (Hultgen[52]). "Probably, in some cases, the removal of fluid under pressure from the intra-dural spaces will prevent the occurrence of suppurative meningitis." (Ballance). Cushing states that the cause of death is "purely mechanical, and is due to intra-cranial pressure. Also that meningitis is a self-limited disease, and if pressure can be relieved and time gained the inflammation will subside and the exudate will be reabsorbed."

"While unconsciousness is a forerunner of paralysis of the vital centers, it should *not* be waited for." (Archibald).

If we have shown that operation is justifiable, that it must be invoked early, the next question is:

F. WHERE SHOULD THE OPERATION BE PERFORMED.

Clearly not at the far end of a long, narrow canal as in lumbar puncture or laminectomy for the reasons already adduced, which are, impossibility of adequate or sustained drainage and the inherent dangers of the procedure itself. Certainly not by a more dangerous and less efficient means, as ventricular puncture. But by an operation which will positively tap the *fons et origo* of the trouble at the base of the brain, namely, the cisterna magna. Ballance was probably the first to attack meningitis by the sub-occipital route. He was followed by Parkin, and Ord and Waterhouse. But the operations performed by them and by others who followed them have not opened the cistern easily and satisfactorily, they have all been attended with many difficulties and grave objections, as will be shown later.

Anatomy shows us that this is the largest subarachnoid space, that it is in the "freest communication" with the other spaces without the brain and cord and especially with the ventricular cavities within the brain through a foramen always large and seldom if ever closed.

Chipault[53] states that he has found only two cases on record in which a communication between the fourth ventricle and the subarachnoid space did not exist, one case reported by Quincke, of chronic meningitis, and one by Keen, of unilateral hydrocephalus.

Anatomy further shows us that the cisterna magna is located close to the lower portion of the occipital bone in a position favorable for operative attack.

Physiology demonstrates that the course of the cerebro-spinal fluid is from the ventricles into the cisterna magna. Normally the current is of moderate force and the fluid in small amount. But, comes infection, the increase in amount becomes enormous and the rate of flow must be proportionately increased, so that we can imagine the fluid streaming into this space like a turbulent river into a broad lake.

Pathology offers its evidence that in this region the fires of meningitis burn fiercest and the debris of such inflammatory conflagration are in greatest evidence.

Campbell and Rowland[54] comment on the pathological findings in 206 cases of pneumonic meningitis, "the base of the brain shows the most marked lesions. The exudate is almost entirely confined to the base of the brain." Koplick,[55] in basic meningitis, found "lymph at the base of the brain and cord." "Thickening of pia and arachnoid at base of brain, some adhesions between cerebellum and medulla." Barlow and Lees, quoted by Koplick, state that the "primary seat of the inflammation is the region where the brain and cord meet and where the cerebellum overlaps the medulla." "Adhesions may result in blocking the foramen of Magendie."

Adami and Nicholls[56] "the exudate tends to collect at the base of the brain and along the posterior aspect of the cord. It is largely serous, but may be turbid. The exudate is found chiefly along the vessels and fills up the cisterns at the base of the brain."

Therefore, the *conclusion* is *inevitable* that the *cisterna magna* is *the best and only reasonable place for surgical interference in meningitis.*

CHAPTER IV.—SURGICAL ANATOMY OF THE SUB-OCCIPITAL REGION.

1. The skin and subcutaneous fascia require no mention. They are divided by a vertical incision immediately in the median line.

2. The muscles lie in paired groups on either side of the middle line; consequently they are not divided in the operation, but merely retraction to one side. They are the trapezius, complexus and the rectus capitis posticus minor.

3. The nerves do not appear at all. The only one which might enter the field is the third occipital. As this is a purely sensory nerve, its division could only cause temporary numbness of the back part of the scalp.

4. The vessels are the only structures of the soft parts which deserve more than a passing remark. They are paired arteries and veins which are connected more or less freely by anastomotic vessels which cross the line of the incision. When divided they bleed, but the hemorrhage is easily checked by clamps.

5. The pericranium is easily stripped from the bone, and with it the portions of the origins of the muscles near the middle line. It is also directly continuous with the atlanto-occipital ligament at the margin of the foramen magnum.

6. A small median emissary vein may exist at about the middle of the occipital crest. It is not constant. If present it may be plugged by a piece of wood or by boring into the opening with the tip of an artery clamp.

7. The skull deserves a longer notice. There is a great difference in the thickness of the skulls in this region in adults. Of course in children it is very thin, with a slight thickening along the occipital crest. In both classes the thickest portion of the bone is at the occipital crest. On either side of the crest the bone becomes thinner, to again thicken up about the foramen magnum. In all cases it should be perforated with due caution.

8. The dura is thick and firm. It is readily separated from the bone. At the foramen magnum it is the most closely attached, but can be readily detached from the bone without difficulty. It is continuous here with the pericranium.

9. The occipital sinus "is the smallest of all the sinuses, about 2 mm. in diameter. It is composed of two parts: a vertical part which descends in the falx cerebelli; a horizontal or anterior part, also called the sinus marginalis, which courses around the margin of the foramen magnum and opens into the lateral sinus." (Poier and Charpy[57]). They also give the following figures as to its varia-

tions: 5 times out of 50 it was very large (Dumont); absent twice in 44 cases; 10 times the marginal branch was absent; in 9 times there were two sinuses; in 33 times there was one trunk unpaired and median, bifurcating at its lower part."

10. The arachnoid presents in this region as a membrane of considerable strength and individuality. It is closely applied to the dura and consequently separated by a wide space from the pia beneath, over an interval corresponding to the apices of the cerebellar lobes and the sides of the medulla.

11. The incisura cerebelli posterior. This gap between the cerebellar lobes is bounded below and in front by the medulla.

12. Covering the surface of the parts will be seen the vascular pia, with the two posterior inferior cerebellar arteries (from the vertebrals) standing out conspicuously as they wind around the apices of the cerebellar lobes from its lower surface into the incisura cerebelli.

13. If the cerebellar lobes are gently raised and separated there will be seen the opening, usually vertically placed and with irregular borders, the foramen of Magendie, which exists in the pia extending from the cerebellum to the medulla.

14. As to the cerebellum and medulla, our surgical and anatomical investigations do not carry us that far at this time.

CHAPTER V.—DRAINAGE OF THE CISTERNA MAGNA FOR MENINGITIS.

A. Purposes of the Operation. B. Steps of the Operation. C. Difficulties of the Operation. D. Advantages of the Operation. E. Secondary Remedial Measures. F. Other Conditions in Which This Operation May be Indicated. G. Instruments and Appliances.

A. PURPOSE OF THE OPERATION.

1. To open the cisterna magna, relieve intra-cranial pressure, and restore the normal supply of "good blood" to the "vital centers."

2. To do this without danger of cerebellar hernia or of "corking up the foramen magnum" by downward displacement of the brain stem.

3. To prevent shock and possible death of the patient from too sudden escape of the cerebro-spinal fluid.

4. To provide for free and continuous drainage of the infected cerebro-spinal fluid and thus enable Nature to effect a cure of the disease.

5. To afford inspection of the foramen of Magendie, and if it be closed, reopening it.

6. To forestall possible complications, especially hydrocephalus If hydrocephalus is present, its relief and cure is possible by this operation.

7. To accomplish these desirable ends by an operation of the simplest technic, in the minimum of time, with the least shock.

B. STEPS OF THE OPERATION.

The scalp has been shaved and the usual preoperative measures taken to secure and maintain absolute asepsis.

The proper position upon the operating table is maintained by the special head-rest (see figure) or by a competent, strong assistant, and sand bags.*

The anesthetic (ether) is administered through nasal tubes beneath the sterile sheet covering the patient.

The incision is in the middle line from the occipital protuberance to the spinous process of the axis and carried down to the occipital bone and posterior arch of the atlas.

Hemorrhage, slight and easily arrested, is checked by mosquito clamps and the vessels ligated.

The periosteum is now stripped from the occipital bone, taking with it the inner portions of the origin of the attached muscles, and the occipital bone is bared for about a distance of one and one-half to two inches vertically and an inch transversely, at the foramen magnum, less above (see illustration).

The posterior arch of the atlas does not require baring.

An emissary vein may be encountered in the mid-line. It is not constant. If present it may be plugged by a wooden toothpick or by boring into it with an artery clamp.

The self-retaining retractor is now introduced. There are two sizes of detachable blades provided, one for adults and the other for children.

The De Vilbiss trephine (three-eighths of an inch) is applied in the mid-line and about one inch from the margin of the foramen magnum and the button of bone removed. With the special dural separations the dura is loosened from the bone and the De Vilbiss bone-cutter used to make two lines of incisions or grooves through the bone into the foramen magnum. The dural separator must be constantly used to detach the dura from the bone in advance of the bone-cutter. For this reason these separators are made in two

*A blood-pressure apparatus is attached to the patient and an assistant detailed to carefully watch this and the pulse and respirations and announce their variations.

sizes and with a narrow shank to easily pass through the groove in the bone.

The wedge of bone, cut loose, is about half an inch wide at the foramen magnum and a little less at the upper border. Of course the size may vary for each individual and according to complications. The detachment of the bone-button is carefully completed and it is removed.

The dura presents, probably under pressure, bulging into the bone gap.

The occipital sinus (or sinuses) will be seen, if present, showing a blue color through the dura. If the sinus is double, the dura should be incised between them. If single, it should be tied at the upper part and just beyond its bifurcation into the marginal sinuses. The special, full-curved, right-angled dural needles, right and left, are provided for this purpose.

Caution:—In dividing the dura, first make a very tiny incision into it, using the fine curved bistoury for this purpose.* This is necessary, for should the arachnoid be so closely applied to the dura as to be divided with it we need to prevent a too sudden escape of the cerebro-spinal fluid. Should it be found that the dura has been severed alone the incision in it should be carried up and down to the limits of the opening in the bone.

The arachnoid will now bulge into the field, unless it has been divided with the dura. The amount of its bulging will give some idea of the degree of intra-cranial pressure. The arachnoid is slightly nicked in the middle line and the cerebro-spinal fluid allowed to escape, a specimen being taken for laboratory examination. While it escapes slowly a careful watch is maintained upon the blood-pressure, pulse and respirations by one especially detailed for this purpose. Syncope may be prevented or lessened by arresting for a moment the flow of the fluid by gentle pressure of the finger.

As soon as the excess of fluid has escaped, open the arachnoid for the full extent of the dural opening. The condition in the cerebello-medullary angle should be very carefully investigated. Should there be an exudate about the parts the lobes of the cerebellum should be raised and separated by the "pushers" provided for this purpose and the patency of the foramen of Magendie assured. It may be necessary to enlarge the opening in the occipital bone. This is easily done by the ordinary rongeurs or by the bone punch

NOTE:—In our first case a small aspirating needle was inserted through the dura into the cisterna magna and the excess of fluid withdrawn. In the other cases the structures were cautiously divided with a knife.

devised by the writer. A small wick of rubber or gutta-percha tissue is placed within the margins of the dura and arachnoid and left protruding from the wound. The muscles are replaced and held together by two or three plain gut sutures (interrupted). The skin is closed above and below the drain with silkworm gut, interrupted sutures. Voluminous dressings are applied, sufficiently thick to fill out the normal hollow between the head and neck.

The patient is handled with care, remembering that the brain stem no longer has its protecting cushion of fluid. The entire operation takes from fifteen to thirty minutes.

C. DIFFICULTIES OF THE OPERATION.

As to the difficulties of the operations already performed by the writer, three in number, there were none. The cisterna magna was easily and quickly reached in all cases, so easily, that it demonstrated perfectly how simple the operation was. As to the emissary vein, it is not constant; it was found in one cadaver of 6, and in one patient of 3, and here bled so little that a twist of an artery clamp into the hole stopped the bleeding at once.

The devision of the bone in the two children was such an easy and rapid proceedure that one needed to be careful not to crowd the trephine too fast. In the adult it took about the same time as on the vertex. The separation of the dura, the removal and reintroduction of the bone cutter took no appreciable time and was not attended with a single bad symptom or drawback. As to the occipital and marginal sinuses, they need not cause one a second's thought. If in the line of the incision, tie them, otherwise not (if double).

Regarding the danger of the escape of cerebro-spinal fluid. This danger attends this no more than any operation upon the skull. However, I think too much stress is placed upon this factor. In a fairly large experience in operating upon the skull and spine, and by perusal of the literature I am convinced that mere loss of cerebro-spinal fluid is not attended with any danger whatever. In cases of meningitis, however, where the brain is under pressure, its sudden escape might be attended with serious syncope. Yet in one of my cases there was an unintentionally large incision made into the cisterna magna and the fluid all escaped within a few seconds, yet no symptoms were observed. In the two other cases the fluid was slowly evacuated, in one through a tiny incision, in another by an aspirating needle, the stream rising in the adult to the height of six inches or more.

Our experience is not large; but in connection with that of others who have recorded their observations, it is helpful and confirmatory.

As to the danger of infection, infection is *already* present. The operation is undertaken to relieve the individual of its effects and possibly cure the disease. No more valid objection against operating in these cases exist than in the presence of infection in any other part of the body—even less—for often unrelieved suppuration elsewhere may spontaneously open and drain itself, but, from the cranial cavity, never.

D. ADVANTAGES OF THE OPERATION.

This operation opens the cisterna magna at its largest and most favorable spot for the evacuation of any fluid it may contain. Drainage established here effectually taps all other adjacent regions within and without the brain and cord. We do not seek to establish drainage merely to provide an exit for purulent cerebro-spinal fluid, but to *relieve intra-cranial pressure and restore blood to the vital centers.*

Furthermore, once drainage is established, the fresh secretions of cerebro-spinal fluid are more potent in their bactericidal elements than before, and every hour gained in life leads to greater probabilities of a complete cure. (We except from this statement cases moribund at the time of operation). The operation is not complicated by the protrusion of the cerebellum into the cranial opening, as occurs in all other operations in the cerebellar fossa. "Hernia of the cerebellum" interfered with Ballance. Parkin had to "push the cerebellum out of the way" before he got any flow, beyond a few drops. Ord and Waterhouse found that the "cerebellum bulged into the trephine opening, fitting it tightly like a cork in a bottle." Hall[56], in operating upon a case after Parkins' method, says "the cerebellum protruded so forcibly that its substance was lacerated against the edges of the bone." In the operation here suggested there is no hernia cerebelli. The reasons are plain, anatomy reveals and surgery proves them.

Meningeal infection is attended with an increased amount of cerebro-spinal fluid. This causes great intra-cranial pressure. The cortical surface of the brain is crowded against the inner surface of the skull. A trephine opening made in the skull anywhere over the convexity of the brain (cerebrum or cerebellum) and the dura divided, the brain is crowded forcibly into the opening and tightly "corks it up." At the site of this operation, over the cisterna magna,

and between the lobes of the cerebellum there is a *normal gap* or hiatus. The skull can be opened here in the presence of great intracranial pressure without a hernia cerebelli occurring or even a tendency to one appearing.

The entire central cerebello-medullary tract is under direct observation and, if required, surgical treatment. Moreover, drains can be inserted, laterally if necessary, for draining the lateral fossae on one or both sides. Should there be adhesions blocking up the foramen of Magendie, these can easily be broken up by merely separating the lobes of the cerebellum without disturbing the medulla. Plugging of the foramen magnum by the brain stem is impossible. The other varieties of operations suggested and performed in the sub-occipital region *do not drain.*

Ballance had to "trephine both sides of the middle line so as to prevent hernia of the cerebellum interfering with drainage." Parkin stated he got "free drainage up to the last," but he had to raise the cerebellum up in order to gain this. Ord and Waterhouse had a similar difficulty to contend with. Kuemmell had to trephine on both sides of the middle line to secure adequate drainage.

If a drain is inserted through a trephine opening as usually placed, the brain must be crowded back. It may be and usually is lacerated in the undertaking. If a drain is inserted it lies between the brain and skull and is pressed upon by the latter. It is soon isolated by enveloping adhesions and ceases to functionate. Drainage by the older operations is difficult and of short duration. But drainage from the cisterna magna is from a cavity. It is not subjected to pressure and there is no tendency to limiting adhesions. Ordinary peritoneal drainage and its speedy isolation by adhesions resembles the former class of cranial drainage, while supra-pubic drainage of the urinary bladder by rubber tissue closely imitates the method of drainage from the cisterna magna here advocated.

As to the plan of Radmann to drain this region by an incision through the occipito-atlantal ligament, the space is very narrow, especially narrow in children, the vertebral arteries come into dangerous proximity to the field of operation, the *opening is below the real seat of trouble.* Relief of pressure at this point is attended with the same objection as for lumbar puncture, the possibility of "corking up the foramen magnum by the brain stem."

Furthermore, no information as to the condition within the great cistern can be obtained and there is no possibility of determining if the foramen of Magendie is closed, and no relief of such a condition, if present, could be offered.

Extra-cranial advantages are that there is a single incision with separation, merely of the muscles. There is no extensive division of muscles as in Ballance's, Parkin's, Ord and Waterhouse's or Cushing's propositions, with their subsequent resuturing—time-consuming details. Nor can there be the "furious bleeding" reported by Ord and Waterhouse. Loss of any considerable quantity of blood is something to be carefully guarded against. Because it "is imperative that the blood-pressure be maintained" (Archibald), and loss of blood results in its lowering.

The operation is quickly done. Fifteen minutes in the child and, at most, thirty in the adult, is ample time in uncomplicated cases.

Further, an operation at this site will prevent future complications. Cerebral irritation and even epilepsy due to adhesions forming between the pia and dura is impossible, as these two membranes are so widely separated at this point. Hydrocephalus, that frequent complication of meningitis, and probably due to the closure at the foramen of Magendie, can be prevented. As to the frequency of hydrocephalus, Lees and Barlow[59] state that in 38 out of 50 autopsies it was the *hydrocephalus*, and not the meningitis, that caused death.

Cushing emphasizes this condition by stating "that basal meningitis of whatever nature, provided the exudate serves to obstruct the foramen near the fourth ventricle, is usually the immediate cause of death in the fatal cases of meningitis, and in those which recover, it is a common source of cerebral disturbance, owing to an incomplete re-establishment of the normally free outlets."

Furthermore, if hydrocephalus has developed, as a sequella of "cured" meningitis, it is probably due to the closure of this outlet. By means of the operation here described, which offers greater access to this region with the minimum risk, simple technic, ease of execution, advantageous position, relief may be secured for these patients.

E. SECONDARY REMEDIAL MEASURES.

Blood-pressure must be maintained and in no instance permitted to fall. A sudden fall in blood-pressure indicates a fatal end.

As to drugs, strychnine is our sheet anchor; adrenalin may be helpful.

Mechanical measures, bandaging the abdomen, over a small pillow, bandaging the lower extremities, lowering the head of the patient (and table if necessary).

Furnish good blood to the asphyxiated vital centers by the inhalation of oxygen.

Saline transfusions or injections during or following the operation. A Murphy drip or intermittent saline rectal enemas of a few ounces continued over the first 24 hours afford one of the best therapeutic measures. It furnishes fluid to the system, flushes the kidneys, aids the other eliminating glands and so assists in throwing off the infection.

Possibly the proper auto-vaccines or anti-toxins may be of some service in combatting the general infection. By large doses of hexamethylenamin the cerebro-spinal fluid may be rendered more anti-germicidal and thus more quickly overcome the infection.

The chief point is, however, that by early resort to surgery all these evidences of systemic poisoning may be prevented, or, if present, to some extent relieved before they have overwhelmed the patient.

F. OTHER CONDITIONS IN WHICH THIS OPERATION MAY BE INDICATED.

I have written this paper to urge the early use of this reasonable and safe operation in meningitis. I feel, however, that it is not by any means restricted to this disease alone, but might prove a life-saver in those basal fractures extending into the posterior fossa of the skull, when death is certain from pressure due to the intracranial hemorrhage as demonstrated by lumbar puncture and compression symptoms.

So many of these cases reach the surgeon in the terminal stage of cerebral compression and bulbar paralysis that it is realized but few may survive the operation. Is it not worth while, however, to give these otherwise fatal cases a chance? Ransohoff[60] states that in 190 cases of fracture of the base of the skull: 56 per cent died within 12 hours; 78 per cent within 24 hours, and 85 per cent within 48 hours. There is thus a margin of from 12 to 24 hours in nearly 30 per cent in some cases in which this method of decompression might be of use.

Furthermore, should infection be added, as not infrequently follows, and a basal meningitis develop, as in Kuemmell's case, would not this operation prove more advantageous than the extensive one proposed by him or similar ones suggested by other surgeons.

The indications are practically the same as in meningitis. But we do not, usually, have the opportunity of observing the cases early. Serious pressure exists, as a rule, when these cases come under observation, as shown by the coma, fixity of the pupils, vagus pulse and irregular respirations. With such extensive bulbar paralysis

operation would hold out very little chance of success. But if there was only delirium or stupor, with a rising blood-pressure, with fair pulse and respirations only stertorous and lumbar puncture gave a bloody fluid, under pressure, drainage of the posterior fossa by this route might be successful in a fair proportion of cases.

G. INSTRUMENTS AND APPLIANCES.

As far as possible "stock" instruments have been selected and tried out upon the cadaver and upon the living. While we have made a few suggestions, tending to meet certain contingencies and to facilitate the operation, the entire operation may be easily performed with the ordinary instruments for cranial surgery. No chisels, gouges or hammers should be used. We have had fashioned a self-retaining retractor by a little modification of a Jansen's mastoid retractor, extending and squaring the arms and using removable tractor blades. The right and left dural ligature passers had to be made especially. There is nothing small enough that has the strength with the proper curve. The dural separators are stock instruments, slightly modified. The sharp triangular periosteal scraper was found useful in separating the dura and pericranium at the foramen magnum. The rectangular bone-punch is intended for enlarging the opening in the bone, in children; in adults the ordinary bone cutters may be used for this purpose.

The hospital head-rest is constructed after the one described by H. B. Smith.[81] We have aimed to make it applicable to any age and adjustable to any table.

The advantage of this head-rest consists first in securing immobility of the patient's head in the best position for work upon the region in question. Further in being attached to the table, the table may be elevated or depressed as occasion may require without disturbing the position of the patient upon it.

I have designed a portable head-rest which may be attached to any table (kitchen or operating), and is also easily adjusted to adults or children. It weighs 6 pounds while the above weighs about 15 pounds.

CHAPTER VI.—RECORDS OF CASES.

Case 1. A. M., Italian, 8 years of age; November 21, 1910. The child was taken sick with influenza one and a half weeks ago. Sickness began with general malaise, pains all over the body and a slight cough, no chills. Temperature 100° to 102°. Diagnosis: Broncho-pneumonia.

Ten days ago a purulent discharge appeared from both ears. There had been no complaint at any time of pain in the ears. Eight days ago the child became dizzy and four days ago had vomiting spells and then gradually became semi-comatose. Pupils did not react to light. Kernig's sign present, and Babinski sign present in both legs.

At this time a petechial rash appeared over the body. Temperature, 101°; respiration, 30. Diagnosed now as tubercular meningitis. Spinal fluid was drawn and diagnosis confirmed by the Board of Health.

Dr. Kopetzky saw the child after this. He found it unconscious, pupils dilated and not reacting to light. Head retracted and rigid on body. Kernig and Babinski signs marked. He withdrew 30 ccm. of spinal fluid and sent the child to the Red Cross Hospital, November 20, 1910. Dr. Kopetzky's diagnosis: Otitic meningitis following a double mastoid.

On entering hospital, temperature, 101°; pulse, 120; respiration, 28. Blood-pressure, Janeway's cardiac sphygmanometer, 98 to 100 mm. Hg. Operations at midnight. Ether anesthesia by Dr. Garr, House Surgeon. Mastoid operations by Dr. Kopetzky, assisted by Dr. Imperatori.

Right side:—Outside surface markings of cortex of mastoid normal, but on removal of cortex, no mastoid cells were evident at all. the sigmoid sinus completely filled up the small mastoid protuberance. It was covered with granulations. The mastoid antrum was finally located, by pushing back the sinus wall, and the region found filled with detritus and pus.

Left side:—Nothing abnormal in structure. Pus and detritus in the process.

Drainage of the cisterna magna by Dr. Haynes, Dr. Kopetzy assisting, and Dr. Imperatori steadying the child's head. An incision was made in the middle line from the external occipital protuberance to about the third cervical spine and down to the occipital bone and the arches of the atlas and axis. Hemorrhage was very slight, four clamps controlled the bleeding. The periosteum and attached muscles were elevated from the bone and pushed toward the sides until the occipital bone was bared from the inion to the margin of the foramen magnum and an inch or slightly more in width. There was no hemorrhage.

A DeVilbiss trephine (three-eighths of an inch in diameter) was applied to the bone midway between the inion and the margin of

the foramen magnum in the middle line. The skull was unusually thick in this place, but the button was turned out without difficulty and the dura exposed. This was loosened about the margin of the hole by the dural separators and a DeVilbiss bone-cutter used to make two furrows from the trephine opening to the foramen magnum. The intervening piece of bone was gradually removed by a flat rongeur. There was no bleeding. There was no appearance of any sinus, occipital or marginal. A medium aspirating needle was inserted through the bulging dura, into the cisterna magna, and enough fluid obtained for laboratory examination (about 10 ccm.).

The dura presented an injected appearance. It was carefully incised in the middle line and the cerebro-spinal fluid allowed to escape, which it did slowly but not satisfactorily. The incision was enlarged and the fluid escaped freely. It looked thin and clear.

The arachnoid presented in the wound as cotton (absorbent) looks when floating on the surface of water. It was somewhat milky in color. Nothing of the cerebellum or blood-vessels showed through it. It was severed in the middle line as deeply as I dared to go with the idea of dividing its meshes and allowing freer drainage. A rubber tissue-drain was inserted into the opening and the wound closed with interrupted plain gut sutures, No. 2. A large dressing was applied and the child returned to bed. Pulse, 144, good quality.

Comments on the operation:—The cerebro-spinal fluid did not seem to be under any considerable pressure, though several ounces flowed away. This was probably due to a lumbar puncture six hours before when 30 ccm. had been withdrawn. The meshes of the arachnoid were "fluffed" up by the fluid so as to be very conspicuous and to obscure all deeper parts. The hemorrhage was inconsiderable at all times. No sinuses were visible and there was no dural bleeding. The method of exposure gave ample room for all work. A much larger amount of bone could easily have been removed if deemed necessary.

Subsequent course:—The drainage of cerebro-spinal fluid was free. Patient roused up sufficiently to take nourishment well up to within a few hours of death. Retraction of the head disappeared the morning following the operation and the limbs became relaxed. Blood-pressure, 95 mm. Hg. The eyes reacted to light.

Patient died 34 hours after the operations of sepsis and toxemia. The heart stopped beating before paralysis of the vaso-motor center. Autopsy was not allowed.

Bacteriological:—Spinal fluid withdrawn by Dr. Kopetzky before the operations, showed a diplococcus without a capsule, probably a pneumococcus. There was, also, present in the culture, a large, unidentified bacillus. No report was made of the fluid obtained directly from the cisterna magna.

Cultures from both ears, showed diplococci. Differential count before operation:—Polys, 30; total leucocytes, 5000; large mono and trans., 14; lympho., 56. After operation (10 hours)—polys, 30; total leucocytes, 16500; large mono- and trans., 17; lymph, 53.

Case 2. H. D., aged 45 years, entered Harlem Hospital, January 12; died, January 15, 1911. Patient has been sick for a week with headaches and general abdominal pain. She worked at housework up to yesterday. Last night she had severe and recurring attacks of vomiting with pain in the abdomen. She now complains of severe headaches and severe abdominal pains, especially in the upper portion of the abdomen. She was admitted as a non-urgent case, probably gall-stones.

Physical:—Muscular female, dusky countenance; conscious, but somewhat irrational; pupils equal, react to light and accommodation; pulse, 120, full volume, tension increased; temperature, 103°; respiration, 30. Abdomen, somewhat tender but nothing localized. Kernig and Babinski absent.

Differential:—W. B. C., 31800; l. lymph, 4; s. lymph, 9; mast cells, 2; polys, 85; January 13, the next day: W. B. C., 33200; polys, 89; l. lymph, 8; s. lymph, 3; Widal negative.

Spinal puncture gave 15 ccm, of turbid fluid under pressure. Laboratory examination:—No blood. Pus cells, large number. Micrococcus lanceolatus, positive. Kernig and Babinski both present.

On January 14, patient was more lethargic. Urine passed involuntarily. Pupils contracted and eyes deviate to left. No convulsions but general spasticity. Cervical muscles especially contracted. She was being transferred to the medical ward by my assistant when I saw the case and ordered her up for operation.

Operation:—Dr. Haynes, assisted by Dr. Boynton and the Hospital Staff. Anesthetic, ether, administered by Dr. Lumbard, hospital anesthetist, by means of the nasal tubes. Time of operation, 25 minutes. Total anesthesia, 35 minutes. Anesthetic well taken. Position on table, on face with head over the edge, as in a reversed Rose-position. Steadied in this position by one of staff.

The occipital bone was exposed by the vertical incision and bared from the inion to the margin of the foramen magnum. Not having a small trephine in working order, a larger one with a diameter of one inch was used, without any trouble, to remove a button of bone from the midline region and midway between the inion and margin of the foramen magnum, from the center of the exposed area.

The bone between the trephine hole and the margin of the foramen magnum was removed with a rongeur, opening up a space an inch wide and an inch and a half vertically.

The dura bulged from the intra-cranial pressure. It was punctured with a small knife, an opening less than an eighth of an inch being made and through this the cerebro-spinal fluid spurted to a distance of six inches or more. A careful watch was kept of the heart and respirations and the flow was checked once or twice by gentle pressure of the finger, although no untoward symptoms had appeared. The wound was then drained with iodoform gauze and the muscles brought together with two or three plain gut No. 2 sutures. The skin closed with silkworm-gut.

Comments on the operation:—I did not open the dura widely in this case, inasmuch as the fluid seemed to escape so freely from the small incision. I think that this might have been done, without adding any danger to the patient or any benefit as the sequel showed.

On return to ward, patient had a general convulsion, but this was the only one she had. Within an hour the pupils reacted to light, the spasticity was less and the wound drained so freely as to soak the dressings.

Four hours later, there was a general improvement in her condition. The pupils were active and there was no deviation of eyes as there had been at a previous examination. Pulse was full and fair quality and running at 150. Respiration, 40; temperature, 102°. Morning of January 15, condition much the same. Kernig and Babinski absent. Wound draining profusely. There is a very free secretion of mucus from the nose and throat—due to nasal anesthesia. Spasticity of muscles much less, especially of the neck. Patient gradually failed and died at midnight, 32 hours after the operation. No autopsy permitted.

Case 3. Admitted to the Red Cross Hospital, April 24, 1911. Died, April 25, 1911. Referred by Dr. L. K. Neff. Baby O'C., 11 months old; breast-fed. The infant had been sick for one week with acute meningitis in which lumbar puncture had been used several times for therapeutic purposes and by which the infecting

organism was shown to be the pneumococcus. On admission, the baby had a temperature, by rectum, of 106°, pulse, 180; respiration, 40. Was in a state of coma with pupils dilated and fixed, head strongly retracted. No record of Kernig or Babinski. Blood-pressure (Dr. Imperatori) 80 mm. Hg. (Janeway's cardiac sphygmomanometer).

Blood-count: White blood cells, 8000; polys, 17; lymph, 61; large mono- and trans., 22. Operation as a last resort. It was completed within 15 minutes. Dr. Haynes, assisted by Drs. Kopetzky and Imperatori, and House Surgeon, Dr. Neff present. Slightest amount of ether used. The operation as detailed in the previous cases was performed. No difficulty in removing the bone or in opening the dura and arachnoid. The opening was made by an ordinary scalpel and was made easily and wider than intended, allowing of rapid escape of the cerebro-spinal fluid. No bad effects were noticed. Clear fluid escaped in considerable quantity. No exudate visible in cisterna magna. The operation was performed at 11:30 a. m.

On return to bed the pulse had dropped to 168, was of good quality. The Murphy drip was started. At 6 p. m., pulse, 170; respiration, 32; temperature (by axilla) 101°. At 6:33 p. m., apparently had a convulsion which lasted 3 minutes. At 8 p. m., blood-pressure, 80 mm. Hg. Four ccm. maternal serum was injected into the flank. At 11:30, temperature (axilla) 102°; pulse, 168; respiration, 36. Patient unconscious. Child died at 1 a. m., without regaining consciousness. Permission could not be obtained for a post-mortem examination.

Comments:—These three cases were in the last stages of septic meningitis. The time for operating had long passed. The operations were performed as a last resort, to offer the only possible chance in a certainly fatal disease. We did not expect to save any of them. However, the demonstration of the rapidity, the ease, the freedom from any disadvantages as an operative proposition was absolute. The cisterna magna was reached, opened, drained and the wound closed within fifteen minutes in the two children and thirty minutes in the adult. Drainage was free, profuse and continuous in all. All the symptoms were ameliorated and death came peacefully.

Operations in such extreme cases are not advocated. They accomplish nothing but an easy death and invite adverse criticism. However, as no one can as yet say absolutely when every case is

beyond assistance, even in these moribund patients I advise interference; possibly one may be saved.

These cases merely emphasize the contention of this paper that this operation must be done *early*. The co-operation of the family physician must be secured. He must learn that the time to operate is just as soon as the diagnosis has been confirmed by lumbar puncture. Delay invariably brings disaster. The argument that because operations in the past have accomplished almost nothing proves nothing except that there must be a change in the time, place and method of operating.

Note:—I would like to express my thanks to Dr. Emil Altman and to Dr. Lewis K. Neff for the opportunity of operating upon Cases 1 and 3.

Case 4. Acute mastoiditis, acute purulent labyrinthitis and streptococcic meningitis. In the service of Dr. Wendell C. Phillips at the Manhattan Eye, Ear and Throat Hospital, New York.

J. H., a Greek, aged 20 years. Came under observation March 19, 1912, giving the following history: There was pain in the left ear, beginning one month ago, followed one week later by spontaneous discharge from that ear. A week before coming to the hospital paracentesis of the membrana tympani was performed. There has been no previous illness.

On admission to the hospital, March 19, he presented all the clinical signs of acute mastoiditis of the left side with infection into the soft tissues behind and below the mastoid process. The discharge from the ear was profuse, yellowish. The temperature at 3 p. m. was 102.4°; pulse, 100; respiration, 26. Eyes reacted to light, patient fully conscious. Tests of the labyrinth showed that it was not functionating, total deafness, absence of caloric and rotation-test reactions, spontaneous nystagmus present. At 9:30 p. m., incision into swelling below and behind mastoid did not evacuate pus. Blood pressure (Janeway) 128 mm. Hg. March 20, 9 a. m., temperature, 102°; pulse, 112; respiration, 24. Complains of intense headache. At 2 p. m., temperature 102.8°; pulse, 80; respiration, 26. Intense headache. Blood-pressure, 146 mm. Hg. (Janeway).

Lumbar puncture performed. The chemical examination of the spinal fluid showed meningitis present, although complete examination was not made (Kopetzky's test).

The fluid, while almost water-clear, showed pus cells upon cytodiagnosis (Strong's examination), and on the next day was reported showing streptococcus present (Strong).

March 21, 3 p. m. Because of advancing signs of meningeal irritation, operation was decided upon. A radical mastoid and labyrinthine exenteration was performed by Dr. Wendell C. Phillips in the usual way and pus and detritus found, but no fistula into the labyrinthine channels was demonstrated. This was followed by *drainage* of the *cisterna magna*, by Dr. S. J. Kopetzy, assisted by Dr. Fresner, who held the patient's head and Dr. McQuade, the House Surgeon. The occipital bone was exposed by a median incision and the parts retracted. A three-eighths inch trephine opening made in the middle line above the foramen magnum and the wedge of bone removed by a chisel and mallet. The dura was exposed and incised. About 40 ccm. of cerebro-spinal fluid was allowed to slowly escape, its flow being controlled by pressure on the edges of the dural incision. The wound was drained by a strip of iodoform gauze and the soft parts loosely closed about the drain by four interrupted sutures. A moist dressing applied and the patient returned to the ward, no stimulation being needed. Patient was reported as comfortable, but not sleeping.

March 22, 10:45 a. m. Blood-pressure, 120-125 mm. Hg. Patient conscious, has no headache. Spontaneous nystagmus still present. (Kopetzky). 3 p. m. Blood-pressure, 130-140 (K.) Urotropin, gr. V and sodii benzoate gr. VIII, ordered. Temperature ranged from 99.2° to 101.4°; pulse, 74-90; respirations, 22-24. He slept during the following night but became restless towards morning.

March 23, 11 a. m. Blood-pressure, 148 mm. Hg. At 3 p. m., temperature, 104°; pulse, 92; respiration, 20. Blood culture taken but later report showed it to have been contaminated. Murphy drip started and continued. Patient was reported as comfortable during the night.

March 24, 1912, noon. Blood-pressure, 132 (K.). Patient had a slight nose-bleed. He was conscious. During the afternoon he became somewhat restless. His eye-grounds were examined, but no signs of pressure reported. Was restless during the night. Temperature, 103.6°; pulse, 86; respiration, 24.

March 25, 6 a. m. Temperature, 101°; pulse, 84; respiration, 24. 1:30 p. m. Patient complained of headache, but no dizziness. Nystagmus gone. Blood-pressure, 140 mm. Hg. Wound dressed by Dr. Kopetzky as drainage seemed to have stopped. One stitch was removed and the gauze drain withdrawn, followed by a spurt of clear cerebro-spinal fluid. Patient complained of intense pain in his head during this procedure. The edges of the wound were

grasped and the flow controlled. The pulse dropped from 90 to 72. A rubber tissue drain was inserted.

Blood-pressure at the conclusion of the dressing was, 118-120 mm. Hg. Patient was left without any headache but still dizzy. At 2:30, an ophthalmoscopic examination showed that the fundus was normal, nerve not swollen, questionable enlargement of veins, very fine nystagmus (Dr. Oatman). He had a comfortable night.

March 26, 2:45 p. m. Blood-pressure, 125 (K.). Hypodermic injection given of 1 ccm. of the combined bacterial vaccines (450 million). At 5:30 he complained of very severe pain in his head, was very restless. One-fourth grain morphin given. Patient rested easily until 5:30 a. m. of March 27. Again became restless and complained of pain in his head. At 11 a. m., blood-pressure, 130 (K.); pulse was soft. Blood culture gave staphylococci (probably agonal, Dr. Callison). During the night patient required one-eighth grain of morphin to control his restlessness. He died during the forenoon of March 28, *perfectly conscious up to the end*. No autopsy was permitted.

Comments:—In addition to this patient's mastoid and labyrinth disease he had a streptococcic meningitis. The *early diagnosis* of meningitis was shown by the rising blood-pressure and by the definite chemical reaction of the cerebro-spinal fluid (the absence of the carbo-hydrate-sugar (Kopetzky), with beginning meningeal irritation. There were none of the usual signs and symptoms of meningitis. His mind was clear, his eye-grounds were normal. His pulse and temperature only reacted to the septic infection. The patient died of septic meningitis without the usual signs of meningitis. Only at the last did he become restless and noisy. There was no stupor, slowed pulse, irregular respirations, or choked-disc invariably found accompaning the usual exitus from meningitis.

The operation distinctly relieved the patient. It did not cure because the infection was too extensive. It demonstrated, however, its value in these otherwise hopeless cases and its use is thereby justified. Some cases will be saved. It is only a question of diagnosis and early operation.

Chapter VII.—Conclusions.

Meningitis kills. The least deadly and after the best treatment 10 per cent to 25 per cent, the other varieties, 100 per cent of cases.

Meningitis kills by producing intra-cranial pressure, anemia of the "vital centers" and their paralysis.

Intra-cranial pressure is assisted in its effects by the constitutional results of infection—septicemia and bacteremia.

The presence of infection is early demonstrated in the cerebro-spinal fluid drawn by lumbar puncture and by the clinical effects of intra-cranial pressure, as recorded by the changes in blood pressure, fundus of the eye, pulse, respirations and state of the sensorium.

These early evidences of meningeal infection are clearly shown by: 1. Progressive increase in blood-pressure; 2. absence of carbohydrates from the cerebro-spinal fluid; 3. edema of the papilla (not "choked disc"); 4. a clouding or irritable sensorium.

Such findings absolutely prove infection is present. If they are present, the diagnosis is certain and the end is sure.

It takes some hours or days for death to occur.

No present therapeutic measures save more than 75 per cent to 90 per cent of diplococcic infections and practically none of all other varieties.

The only relief is by early, free, and continuous removal of the rapidly forming cerebro-spinal fluid, thus preventing cerebral compression, bulbar anemia and paralysis and death.

Anatomy, physiology, pathology and surgery show the cisterna magna the place best suited for such a purpose.

The operation which reaches this in the minimum of time, with the least structural disturbance, with freedom from hemorrhage, with maximum access to the region without cerebellar hernia, with provision for adequate and sustained drainage, with opportunity to explore and treat adjacent parts and prevent complications and with the greatest safety to the patient is the preferable one.

The operative procedure here submitted for draining the cisterna magna fulfills these requirements more completely than any heretofore proposed or performed; therefore, it should be the operation of choice for the treatment of meningitis.

Chapter VIII.—Bibliography.

1. Editorial in the *Lancet*, 1905, p. 1010.

2. Gross, G. W.: *Am. Jour. of the Med. Sci.*, 1873, Vol. 66, pages 57 and 63.

3. von Beck: *Mitteil. a. d. Grenz. d. Med. u. Chir.*, 1896, Vol. 1, page 247.

4. Quincke: Verhandlungen des Cong. für Innere Med., 1891, Vol. 10.

5. Robson, W. Mayo: *Brit. Med. Jour.*, Dec. 6, 1890.

6. Wynter, W. Essex: *Lancet*, May 2, 1891.

7. Corning, L.: *N. Y. Med. Jour.*, 1885, Vol. 42, page 483.

8. Morton, Chas. A.: *Brit. Med. Jour.*, Oct. 17, 1891.

9. Horsley, Victor: Surgery of the Central Nervous System. *Brit Med. Jour.*, Dec. 6, 1890.

10. Ballance: *Brit. Med. Jour.*, 1897, page 1092.

11. Parkin, Alfred: *Lancet*, July 1, 1893, page 21, et seq.

12. Morton, Chas. A.: *Brit. Med. Jour.*, April 8, 1893.

13. Ord and Waterhouse: *Lancet*, March 10, 1894.

14. Fischer, Louis: *Medical Record*, Aug. 13, 1904, page 248.

15. Rolgaus: *L'etat Actuel d. l. Chir. Nerv. Chipault*, 1902, p. 665.

16. Sokolov: *Chir. Nerv. Chipault*, 1903, Vol. 2, p. 44.

17. Gradenigo: *Arch. fuer Ohrenh.*, Bd. 47, Hft. 3, S-155.

18. Chipault: *Chir. Operat. du System Nerv.*, Vol. 1, 1894, p. 724.

19. Witzel: *Mitteil. a. d. Grenz. d. Med. u. Chir.*, 1901, Bd. 8, p. 388.

20. Rolleson and Allingham: *Lancet*, April 1, 1899, p. 889.

21. Macewen: Pyogenic Diseases of the Brain and Spinal Cord. 1893.

22. Hinsberg: *Arch. of Otol.*, Vol. 35, No. 5.

23. Friedrich: *Deut. med. Wchnschr.*, 1904, No. 32.

24. Held and Kopetzky: Surgery of the Ear. Kopetzky, p. 252, et seq.

25. Kuemmell: Verhand. der Deutsches Gesellschaft fuer Chir., 1905, Vol. 34, p. 517.

26. Widal and Ramond: *Brit. Med. Jour.*, Nov. 10, 1906.

27. Dunn, C. H.: *Jour. A. M. A.*, July 22, 1911, p. 259.

28. Radmann: *Mittl. a. d. Grenz. d. Med. u. Chir.*, Vol. 18, 1907-08, p. 501.

29. Fischer, L.: *N. Y. Med. Jour.*, March 26, 1910.

30. Pollack: *Deut. med. Wchnschr.*, May 19, 1910.

31. Bramann: *Arch. f. klin. Chir.*, Oct. 14, 1911.

32. Brem and Zeiler: *Am. Jour. Dis. Children*, June, 1911.

33. Cunningham: Text-book of Anatomy, 1909.

34. Lees, D. B.: *Brit. Med. Jour.*, May 1, 1897, p. 1092.

35. Ballance: Surgery of the Brain and its Meninges, 1907.

36. ARCHIBALD, E.: American Practice of Surgery, Bryant and Buck, Vol. 5, 1908, p. 100 et seq.

37. GRAY: Anatomy, Descriptive and Surgical, 1908.

38. HOWELL: Howell's Physiology, 1911.

39. GISS, E.: Mitteil. a. d. Grenz. d. Med. u. Chir., Bd. 8, 1901, p. 613.

40. KOCHER: Nothnagel Spec. Path. u. Therap., Bd. 9, Theil. 3, p. 73 et seq.

41. KEEN, W. W.: Surgery, its Principles and Practice, 1908, Vol. 3, p. 116.

42. CUSHING, HARVEY: Writing the chapter on the Surgery of the Head in Keen's Surgery, 1908, Vol. 3.

43. CLARK, BRUCE: *Brit. Med. Jour.*, Dec. 6, 1890, p. 1294.

44. FRAZIER: *N. Y. Med. Jour. and Phila. Med. Jour.*, Feb. 11, 1905, p. 275.

45. SLADEN, FRANK J.: Johns Hopkins Hospital Reports, Vol. 15, 1910.

46. FLEXNER, S.: *Jour. A. M. A.*, Oct. 30, 1909.

47. DE MERIC, H.: *Med. Press*, March 9, 1910.

48. HUTINEL: *Presse Med.*, Vol. 28, 1910.

49. RYFKOGEL: *Jour. A. M. A.*, Nov. 12, 1910.

50. NETTER, COURTOIS-SUFFIT AND DUBOSC: *Re. Int. d. Med. et d. Chir.*, Jan. 25, 1910.

51. HINSBERG: *Ztschr. f. Ohrenh.*, Bd. 38, p. 126.

52. HULTGEN, J. F.: *Am. Jour. Med. Sci.*, March, 1910, p. 344.

53. CHIPAULT: *Traveau d. Neur. Chir.*, 1896, p. 256.

54. CAMPBELL AND ROWLAND: *Am. Jour. Med. Sci.*, April, 1910, p. 536.

55. KOPLICK: Mt. Sinai Hosp. Rec., Vol. 4, 1903-4, p. 103.

BARLOW AND LEES: Quoted by Koplick, above.

56. ADAMI AND NICHOLLS: Principles of Pathology, Vol. 2, 1909.

57. POIRIER ET CHARPY: Traite d'anatomie humaine, Vol. 2, p. 980, 1901.

58. HALL, R. J.; CHIPAULT: Travaux d. Neur. Chir., 1897, p. 67, et seq.

59. LEES AND BARLOW: Quoted by Archibald, 36.

60. RANSOHOFF: *Med. Rec.*, May 28, 1910, p. 944.

61. SMITH, H. B.: *Jour. A. M. A.*, Nov. 26, 1910, p. 1859.

62. SOPHIAN, A.: *Jour. A. M. A.*, March 23, 1912, p. 843.

ARMOUR: *West Lond. Med. Jour.*, Vol. 14, 1909, p. 35.

BAILEY: *Med. Rec.*, Feb. 11, 1905, p. 406.

BAISCH: *Beitr. z. klin. Chir.* Tubing., No. 60, 1908, p. 479.

BARLOW: *Brit. Med. Jour.*, Vol. 1, 1891, p. 1091.

BERIEL: *Bull. Soc. med. d. Hop. de Lyons*, 1909.

BERNSTEIN: *Med. News*, June 17, 1905.

BERTELSMANN: *Deut. Med. Wchnschr.*, No. 18, 1891.

Bibliography of Cerebro-spinal Meningitis in the N. Y. State Medical Library, from Jan., 1895, to May, 1905, is containedin the *Albany Med. Annals*, June, 1905, p. 438, et seq.

BRAMWELL: *Clin. Stud.*, Edin., Vol. 7, 1908-9, p. 97.

CARR, J. W.: *Brit. Med. Jour.*, April 17, 1897.

CHAUVASSE ET MAHU: Rapport presentee a'la Soc. franc. d'Otologie de Laryngol. et de Rhinol., October, 1903.

CONNEL: *Quarterly Jour. Med.*, Vol. 3, 1909-10.

CORNING: *Med. Rec.*, Vol. 33, 1888, p. 291.

COUNCILMAN, W. T.: *Albany Med. Annals*, March, 1905, p. 147.

Cunningham's Memoirs, Dublin Academy House, 1892, p. 306.

CUSHING: *Mitteil. a. d. Grenz. d. Med. u. Chir.*, Bd. 9, Heft 4, u. 5.

CUSHING, H.: *Jour. A. M. A.*, Jan. 16, 1909, p. 184.

DAVID: *Jour. d. Soc. med. de Lille*, Vol. 1, 1909, p. 49.

DENCH, E. B.: *Am. Jour. Med. Sci.*, Feb., 1910, p. 157.

DENCH: *International Clinics*, 1909, p. 240.

DOCHEZ, A. R.: *Jour. Exp. Med.*, Vol. 11, 1909.

ELSNER: *Med. Rec.*, Feb. 11, 1905, p. 406.

EVANS: *International Jour. Surg.*, Vol. 22, 1909, p. 206.

EVANS: *Jour. Med. Surg.*, Mobile, Vol. 14, 1909, p. 197.

EVE, F. C.: *Lancet*, April 22, 1905, p. 1067.

EYSTER, BURROWS AND ESSICK: *Jour. Exper. Med.*, Vol. 11, 1909.

FISCHER, L.: *Med. Rec.*, Aug. 13, 1904.

FLEXNER, S.: *Brit. Med. Jour.*, Oct. 20, 1906, p. 1023.

FLEXNER, S.: *Trans. Assn. Am. Physic.*, Phila., 1908, p. 23.

FRAZIER: *Univ. Penn. Med. Bull.*, April-May, 1906.

Fullerian Lectures, Vol. 6, 1892, p. 223.

HAND, A.: *Am. Jour. Med. Sci.*, Vol. 120, 1900, p. 463.

HARTLEY: *Jour. A. M. A.*, Jan. 9, 1909, p. 99.

HASTINGS: *Med. News*, June 17, 1905.

HEIDENSHEIM: *Lancet*, May 20, 1905.

HOELKER: *Ber. klin. Wchnschr.*, No. 34, 1907.

HOLT, L. E.: *Am. Jour. Dis. Child.*, Jan., 1911.

HOLT: *N. Y. State Jour. Med.*, Vol. 9, 1909, p. 239.

HORDER, T. J.: Clinical Pathology, 1910.

HORSLEY: *Brit. Med. Jour.*, Vol. 1, 1888, p. 534.

HORSLEY: *Brit. Med. Jour.*, Vol. 1, 1909, p. 513.

HUBER, F.: *Med. News*, May 27, 1905.

IRWIN: *Lancet-Clinic*, 1909, p. 69.

JAKSCH, R. VON: *Quart. Jour. Med.*, Vol. 3, 1909-10.

KENDALL, F.: *Brit. Med. Jour.*, Dec. 6, 1890.

KING, H. D.: *Jour. A. M. A.*, Feb. 10, 1912, p. 403.

KNAPP: *Arch. of Otol.*, Aug., 1907.

KOHTS: *Monatschr.*, No. 11, 1900.

KREBS, G.: *Therapeut. Monatsh.*, May, 1910.

LEYDEN AND GOLDSCHEIDER: Nothnagel Sammel. Werk., 1897.

VON LEYDEN: *La Semaine Medicale*, July, 1896.

MACEWEN: *Lancet*, Vol. 1, 1887, p. 616.

MACEWEN: *Brit. Med. Jour.*, Vol. 2, 1888, p. 302.

MACEWEN: *Glasgow Med. Journal*, Vol. 24, 1893, p. 354.

MCKERNON, J. F.: *Jour. A. M. A.*, Jan. 9, 1909.

MORSE, J. L.: *Arch. of Ped.*, March, 1911.

NETTER: *Bull. Soc. Med. Hopit.*, 1900.

OPPENHEIM AND BORCHARD: *Deut. Med. Wchnschr.*, Jan. 13, 1911.

OPPENHEIMER, S.: *N. Y. State Jour. Med.*, April, 1911, p. 175.

ORMEROD, J. A.: *Lancet*, April 29, 1905, p. 1117.

QUINCKE: Sammlg. Klin. Vortraege, No. 67, p. 655.

OSBORNE: *N. Y. Med. Jour.*, Feb. 17, 1906.

RICHARDS, J. D.: *Arch. Otology*, Vol. 34, 1905.

RIMBAUD: *Montpel. Med.*, Vol. 29, 1909, p. 153.

ROBINSON: *Arch. Int. Med.*, May, 1910.

RUSSELL, N. G.: *N. Y. State Jour. Med.*, Oct., 1910, p. 457.

SCHULTZ: *Deut. Arch. f. Klin. Med.*, Bd. 89, Nos. 5-6, 1907.

SHIELDS, SPILLER AND MARTIN: *Univ. Penn. Med. Bull.*, Vol. 22,

SPILKER, W. G.: *Jour. A. M. A.*, Feb. 19, 1910, p. 579.

SPILLER AND SHIELDS: *Univ. Penn. Med. Bull.*, Dec., 1909.

SOPHIAN, A.: *Arch. of Ped.*, March, 1911.

TILLMANNS, H.: *Brit. Med. Jour.*, Oct. 3, 1908.

WERTHEIMER: *Muench. med. Wchnschr.*, June, 1904, p. 1004.

WEST: *Med. Jour.*, Columbus, Vol. 5, 1909, p. 323.

WINKLER AND GOHL: L'etat Actuel de la Chir. Nerv. Chipault, 1902, p. 668.

WINKLER AND ROLGAUS: L'etat Actuel de la Chir. Nerv., Chipault, 1902.

WOLLSTEIN, MARTHA: *Jour. Exp. Med.*, Vol. 11, 1909.

1909-10.

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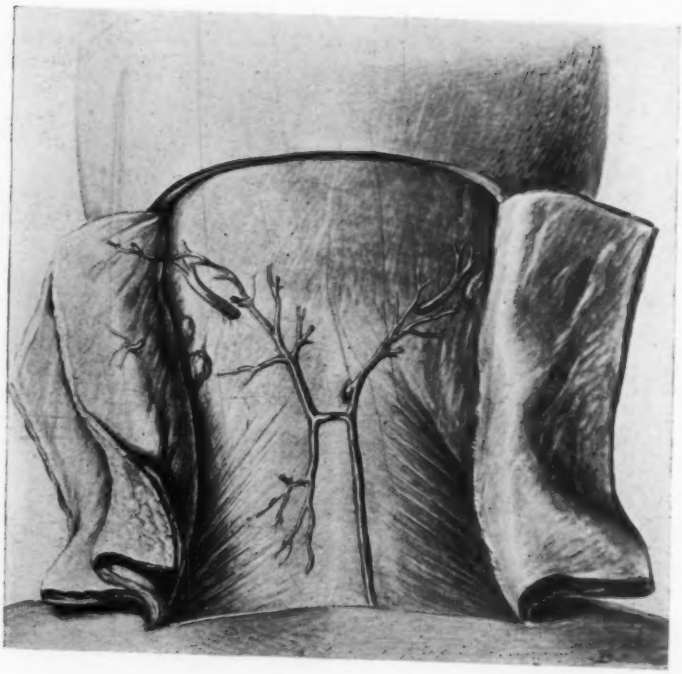

Figures 1, 2, 3. Dissections by the Writer.
Drawn by Mr. Bosse, reduced.
Veins injected to make them more prominent.
Figure 1. Dissection of the post-cervical region superficial to the trapezius muscle. A small anastomotic vein is shown crossing the line of the incision.

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Figure 2. Structures superficial to the complexus muscle.

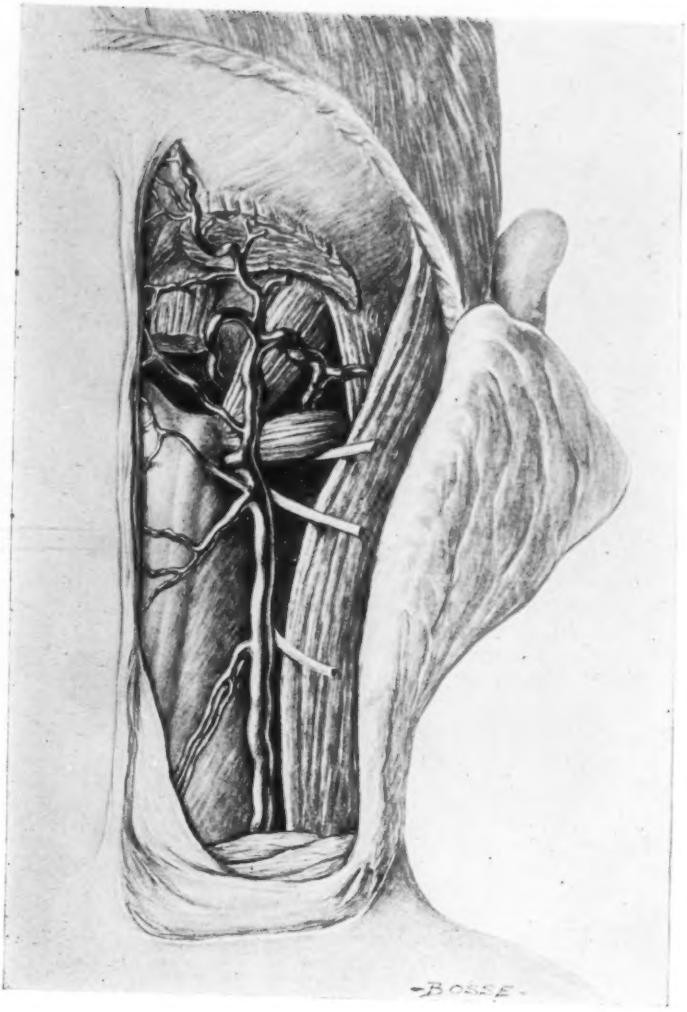


Figure 3. The deeper structures. The small anastomotic veins which cross the line of the incision.

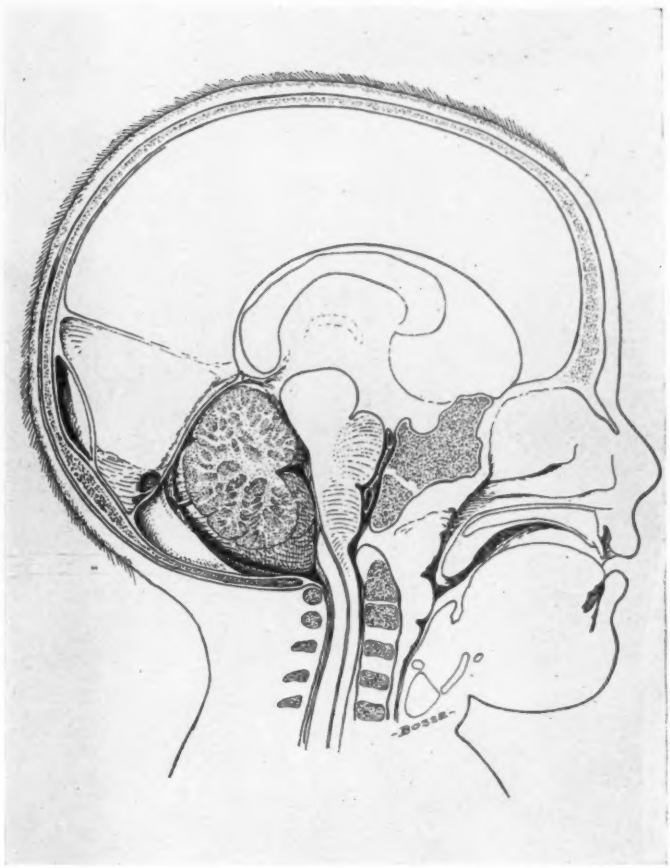
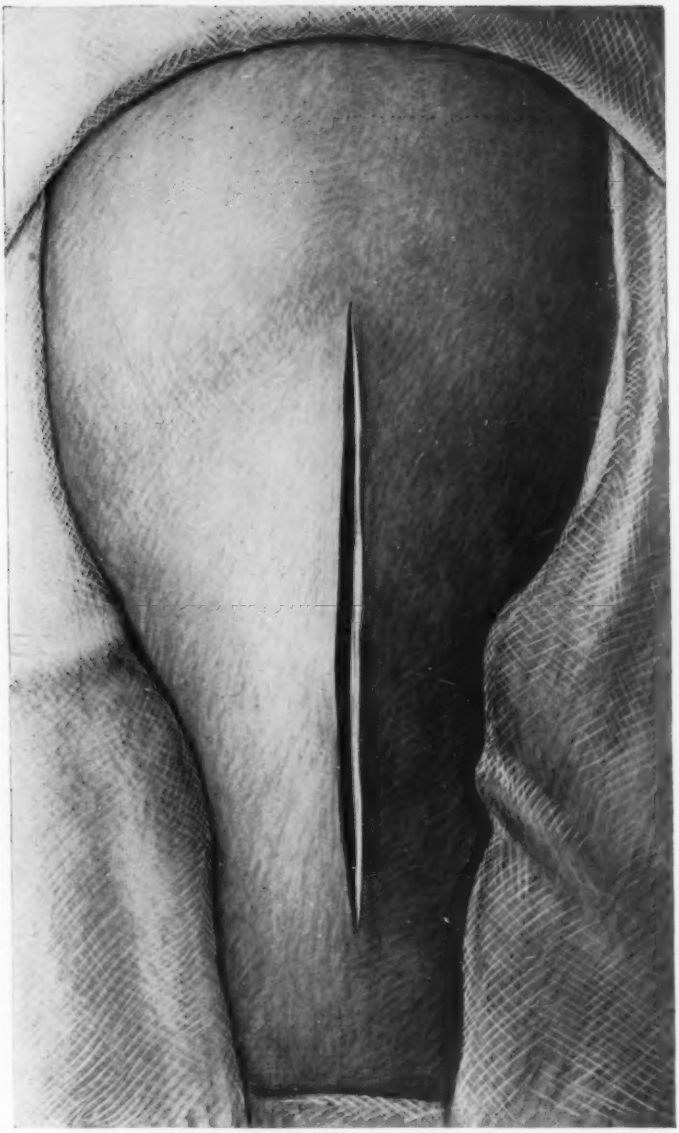


Figure 4. Saggital section of the head and neck of a child. The subject had been hardened in formaldehyde and sectioned by the writer; (slightly reduced).

Note:—Vertical position of brain stem. Its relation to the foramen magnum. The ease with which "corking" this foramen could occur.

The large cisterna magna, its relations to the other subarachnoid spaces and especially to the occipital bone near the foramen magnum. Also the very narrow space between the foramen magnum and the arch of the atlas.

The distance of the skin from the occipito-vertebral angle is greatly diminished by flexion of the head and spine.



Figures 5 to 12. Illustrate the steps in the operation of "Draining the Cisterna Magna."

Preparations by the writer upon an adult male subject. Figures 5 to 8 are slightly reduced. The remaining, on a scale twice that size.

Figure 5. The incision.

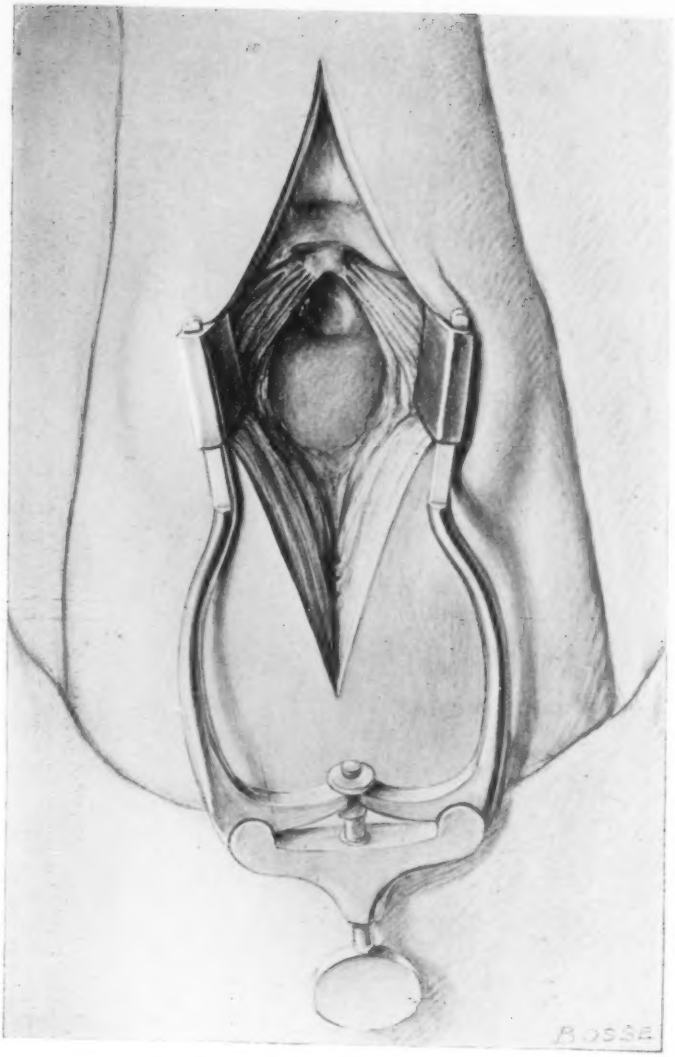


Figure 6. The incision has been carried down to the occipital bone and posterior arch of the atlas. The pericranium with the muscles has been reflected from the occipital bone. The field is fully exposed by the aid of the self-retaining retractor.

Figure 7. The trephine opening has been made and grooves have been cut into the foramen magnum.

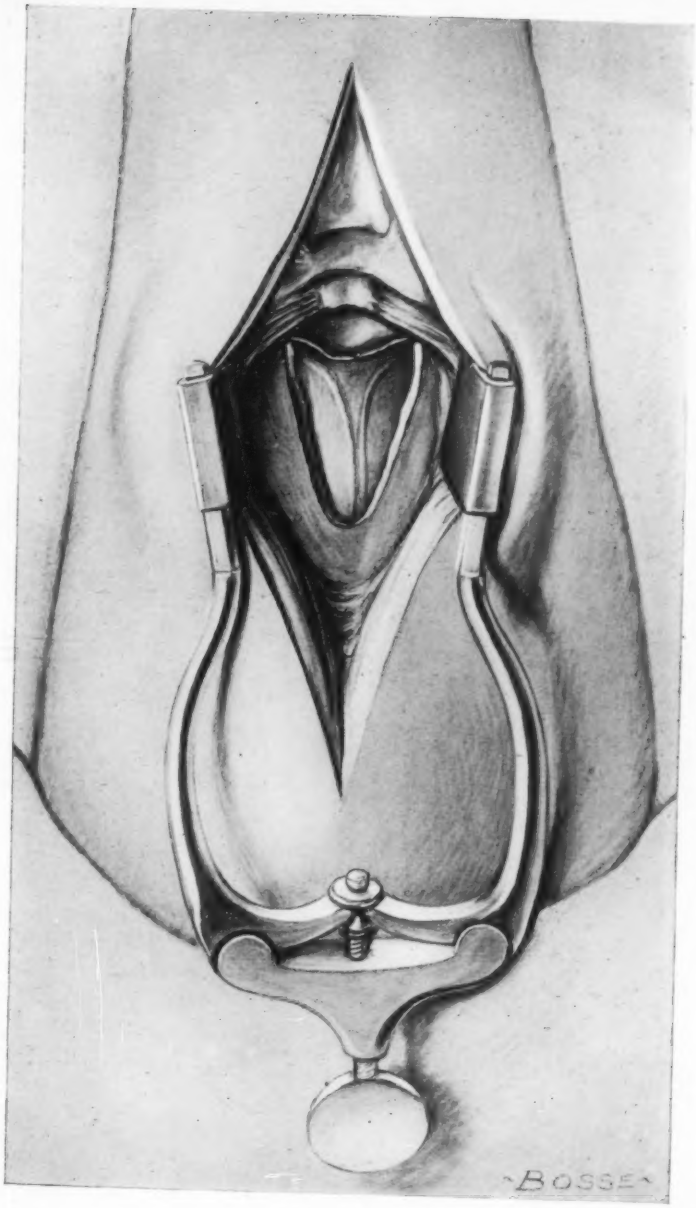


Figure 8. The wedge of bone has been removed. In this cadaver the occipital sinus was double, as shown in the illustration, and both clearly visible.

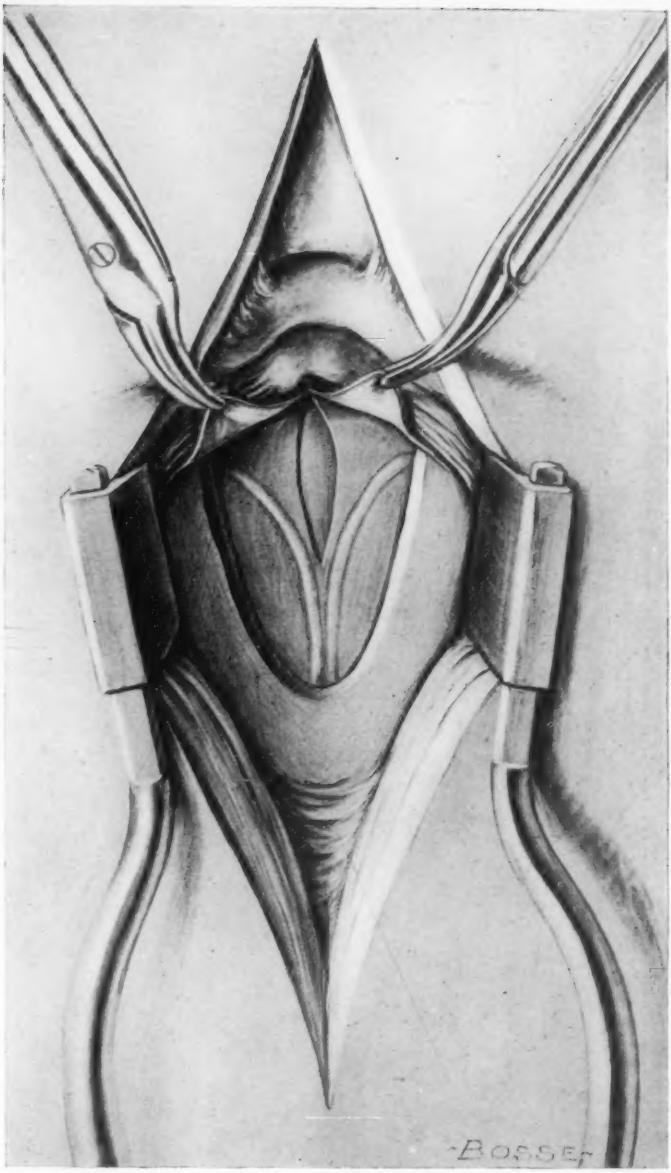


Figure 9. This figure and the two following have been drawn twice the natural size to render the structures more distinct. The dura has been opened between the double occipital sinus and the arachnoid is presenting.

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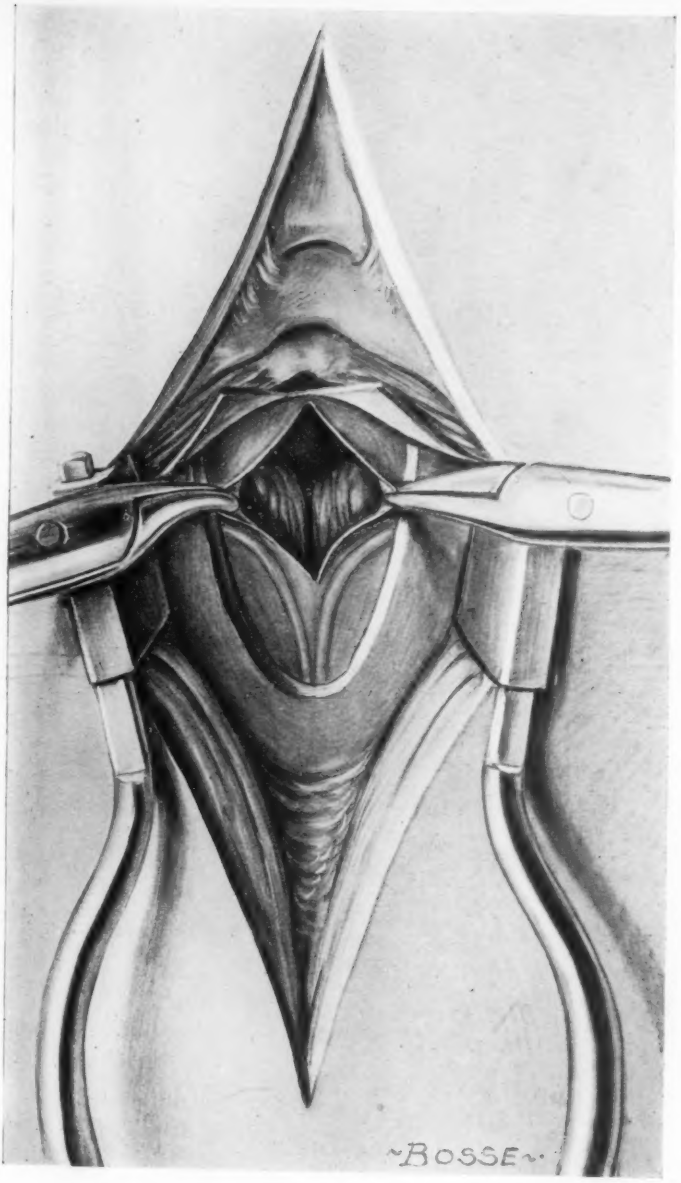

Figure 10. The arachnoid had been divided and the cisterna magna opened. Note the space between the lobes of the cerebellum and the medulla.

Figure 11. The sinuses have been ligated and the dura and arachnoid widely reflected. The two arteries shown curving around the poles of the cerebellum are the posterior inferior cerebellar. They seem to be in close relation with the medulla. They are not. It is impossible to represent, in an illustration, the real depth of the cistern at the bottom of which lies the medulla.

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Figure 12. The instruments which will be found useful in performing this operation. It will be noted that the most of them are "stock" instruments, found everywhere, and do not require even mention.

Attention is called to the self-retaining retractor which is of great assistance in maintaining the wound fully exposed. Also, to a bone cutter, which has a reversible cutting end that may be used in four different positions. Further, to the cerebellar "spoons or pushers" with which the lobes of the cerebellum may be gently pushed upward and apart.

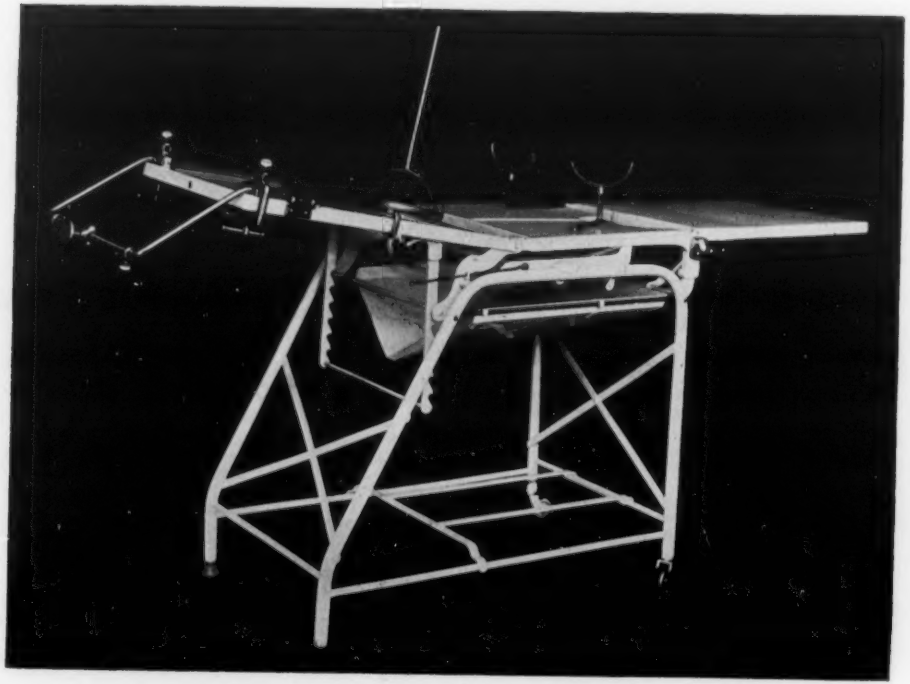

Figure 13. Detached portions of the head-rest shown.

Figure 14. The head-rest assembled. The table should be horizontal. It was inclined by the photographer.

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Figure 15. Shows the position of a patient with the head rest in use. In practice fixation of the head is secured by placing towels in the head piece until a tight fit is obtained for the head.

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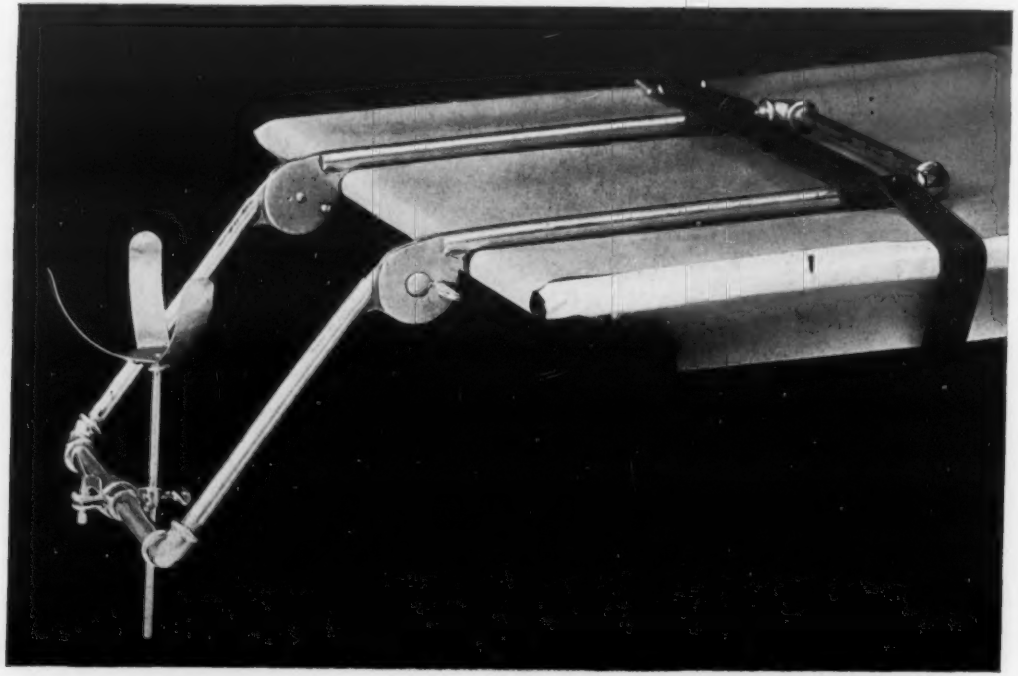

Figure 16. The author's head-rest attached to a common kitchen table by a webbing trunk strap.

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BOOK REVIEWS.

The Voice, Its Production, Care and Preservation.

By Frank Miller, M. D., with a note by Gustav Kobbe. Pp. VI-196. Price, $1.25. G. Schirmer, New York, 1910.

Educated as a practical singer, and trained for many years as a laryngologist, Dr. Frank Miller is especially qualified to produce the little volume on "The Voice" here considered. There are many laryngologists who have frequent occasion to treat professional singers for the many difficulties and indispositions which over-use or faulty production of the vocal mechanism may induce, but the author has the additional advantage of long training as a professional singer, and is therefore more familiar not only with the physiology of voice-production, but also with the psychological factors—mentality, artistic temperament, and correct interpretation of the singer.

Dr. Miller considers in a series of twelve chapters, a rational vocal method; the choice of teachers; breathing; the physiology and psychology of voice production; pitch; registers of the voice; subdivisions of the voice; the stroke of the glottis; vocal hygiene; nodes and their cure.

This monograph is written in popular style and is of inestimable value to laryngologist and singer alike. M. A. G.

Essentials of Laboratory Diagnosis; Designed for Students and Practitioners.

By Francis Ashley Faught, M. D., Philadelphia. Third edition, p. 338, illustrated. Price, $2.00. F. A. Davis Company, Philadelphia, 1911.

This book of 338 pages is intended by the author to provide for the student and busy practitioner a working outline of clinical and laboratory methods without burdening them with tedious details. The subject is presented in a concise manner and is thoroughly up-to-date. All new methods that have proved successful are detailed. Some of the subjects treated are: the selection and use of the microscope; the sputum; the blood; opsonic methods; blood-pressure; coagulation; blood parasites; cerebro-spinal fluid; bacteriological methods, etc. All of these subjects come within the scope of the oto-laryngologist, and he will find the material here presented in so concise and practical a manner of especial interest. We heartily endorse the work.

Die Ohrenheilkunde des praktischen Arztes.

By Dr. William Hasslauer, Munich. Pp. 419, with 124 illustrations in the text. Price, unbound M. 8; bound M. 9. J. F. Lehmanns Verlag, Munich, 1911.

The foreword of the author reads: "Aus der Praxis fuer die Praxis" (Experiences in practice for the general practitioner). This foreword explains in brief the purpose of this volume. It is intended to serve as a practical guide to the general practitioner in the treatment of diseases of the ear.

The first section is devoted to a discusison of the means of examining the ear, nose and pharynx; the most necessary instruments required for this technic; and suggestions to overcome the difficulties ordinarily encountered.

The second part includes chapters on the discussion of the more frequent diseases of the external ear, including frost-bite, burns, injuries and infections of the auricle, and impaction of cerumen, inflammations and foreign bodies in the external auditory canal. Injury of the tym-

panic membrane, and acute inflammation of the middle-ear and Eustachian tube are considered in greater detail.

A key-note to the significance of this book is contained in the expression, "What should and must the general practitioner know of diseases of the upper respiratory tract, and what are his limitations in the treatment of these diseases."

A series of paragraphs discussing the more common pathologies of the nose, naso-pharynx, fauces and larynx follows, which conclude with a discussion of the influence of these pathologies of the upper air-tract upon the ear.

Chronic disease of the middle-ear cavity and the most salient points in diseases of the internal ear are carefully considered.

A valuable chapter has also been added on simulation, hysteria, traumatic neurosis, and the importance of bone-conduction and tuning-fork tests in the differential diagnosis of ear diseases.

The three last subdivisions contain directions for the official reporting of accidents and injuries to the ear, especially in military and civic service. The concluding chapter of the book presents practical therapeutic data and the most commonly employed prescriptions and medicines for the treatment of the more frequent diseases of the ear.

THE NINTH INTERNATIONAL OTOLOGICAL CONGRESS.

The Ninth International Otological Congress will be held at Boston, from August 12 to 17, 1912, in the new medical school buildings at Harvard University. The first circular letter issued by the officers of the Committee of Organization, July 1, 1911, met with a very satisfactory response and more than one hundred members were promptly enrolled: 20 of these being from Europe. In addition to those who have forwarded signed registration cards responses and inquiries have been received from such a number of our foreign confreres as to indicate that there is likely to be a good attendance from abroad. A second circular letter, under date of March 15, 1912, has been issued, containing more specific information and as it is approaching closer to the time for the Convention it seems reasonable to presume that it will bring forth a much larger registration than did the first letter. There is always some delay attending such matters and many seem to prefer direct registration at the time of the meeting. Of course, registration may be made at any time up to, or during, the sessions of the Congress, but if made at an early date by mail it would greatly facilitate arrangements for the accommodation and entertainment of members, their families and guests.

A tentative scientific program has been arranged but as there is still room for a few papers, those who have any new or interesting work of sufficient merit to justify presentation at an International gathering of specialists should immediately communicate with the Program Committee, of which Dr. B. Alexander Randall, 1717 Locust Street, Philadelphia, is Chairman.

In addition to the papers and reports to be presented, there will be an opportunity for a general discussion of several interesting topics. For this purpose the last hour and a half of each afternoon session will be

set aside. One such session will probably be occupied by a demonstration and discussion of the value of radiographs and trans-illumination of the mastoid; another will probably be given to a consideration of the various modifications of the operation of tympano-mastoid exenteration.

There will be five special loan exhibits to which members of the Congress are invited to contribute:

(1) Exhibit of radiographs, showing normal and pathological conditions of the temporal bone, under the Chairmanship of Dr. H. S. Birkett, 252 Mountain Street, Montreal, Quebec.

(2) Exhibit of macroscopic otologic specimens; Chairman, Dr. W. Sohier Bryant, 41 E. 33rd Street, New York.

(3) Exhibit of microscopic otologic specimens; Chairman, Dr. Geo. E. Shambaugh, People's Gas Building, Chicago, Ill.

(4) Exhibit of American books, reprints, photographs, drawings and illustrations relating to otology; in charge of Dr. Thos. J. Harris, 117 E. 40th Street, New York.

(5) Exhibit of otologic instruments and apparatus (this to be a purely scientific and not a commercial exhibit); Chairman of Committee, Dr. Harris P. Mosher, 828 Beacon Street, Boston, Mass.

The specimens contributed to these exhibits will be in charge of the respective Chairmen and under the guardianship of officers of the University. It is earnestly to be desired that every American otologist should send either his collections or even single specimens for exhibition at this Congress.

Among the papers already promised by foreign members of the Congress are the following:

"Some points in the comparison of the two temporal bones; illustrated by specimens and lantern slides," Arthur H. Cheatle, London.

"Functional testing of the ear," Robert Barany, M. D., Vienna.

"The pathology, pathological anatomy and treatment of the infected labyrinthine processes," B. Alexander, M. D., Vienna.

"Abnormal fistulization of the mastoid," E. J. Moure, M. D., Bordeaux.

"Demonstration of microscopic specimens of the internal ear," Urban Pritchard, M. D., London.

(1) "The operative treatment of labyrinthine vertigo." (2) "The eighth cranial nerve, its development and the continuity of the auditory sense epithelium with the auditory nuclei in the hind brain," Wm. Milligan, Manchester.

"The pathology of the labyrinth," Erich Ruttin, M. D., Vienna.

(1) "Symptoms which may arise with cases of aural suppuration and indicate the necessity for prompt conservative mastoid operation, in order to prevent the loss of life or hearing." (2) "The technic of a conservative mastoid operation designed with a view of preventing deafness, disfigurement and unnecessary removal of bone." Chas. Heath, London.

"Ueber den gegenwaertigen Stand unserer Kenntnisse von der Otosklerose," Alfred Denker, M. D., Halle.

"Demonstration von mikroscopischen Prepareta im Projectionsapparat. (a) Normales Ohr. (b) Otosklerose. (c) Taubstumheit. (d) Acustische Labyrinthschadigund," F. Siebenmann, M. D., Basle.

"Subpericsteal mastoid abscess, without intra-osseous suppuration,' A. Luc, M. D., Paris.

"The diagnosis and treatment of lateral sinus thrombosis of otitic origin," Hunter Todd, M. D., London.

"The prevention of deaf-mutism," Macleod Yearsley, M. D., London.

"The training of the young deaf child," G. Hudson-Makuen, Philadelphia.

"The disposal of the deaf after the school-age," Max A. Goldstein, Saint Louis.

(1) "Ear affections of the insane." (2) "Quinin deafness." Fernandez Y. Hernandez, M. D., Havana.

"Epithelial grafting after mastoid exenteration." Chas. Ballance, London.

"Intradural abscess occurring in chronic purulent otitis media," J. Walton Browne, M. D.

"Case of early otoscierosis treated by radium," Richard Lake, M. D., London.

"The after-treatment of mastoid operations," J. Walter Wood, M. D, London.

(1) "Pathogenie inflammatoire de plusieurs fibromes de la caisse et du conduit auditive." (2) "Les neuro-labyrinthitis des la syphilis recent et le salvarsan." Prof. Uffdott S. Citelli, Catania.

"Fibroma or fibro-angioma of the middle ear," A. J. Brady, M. D., Sydney, N. South Wales.

(1) "Diagnostiche Bedeutung des Vestibularapparates," (2) "Histopathologische Demonstrationen." H. Neumann, M. D., Vienna.

"Sulla morfologia dell'orecchio esterno-compresa la M. T. studiata in 100 bambini nati da pacheore a 15 giorni nei Brefotorfi di Firenz e di Pisa." Prof. V. Grazzi, Florence, Italy.

"Inadequacy of the drainage obtained in many cases of acute purulent otitis media, by means of the ordinary myringotomy; a consideration of its remedy." Robert Lewis, M. D., New York.

"Practical results of routine tuning-fork tests," J. Holinger, M. D. Chicago.

"The significance of choked-disc in the complications of aural disease,' Emil Gruening, M. D., New York.

"A periosteal flap to prevent recurrence in acute mastoid and to secure prompt healing of the exenteration operation," Geo. A. Leland, M. D., Boston.

The social features of the Congress will include luncheons each afternoon extended by one or other of the several national special societies; the President's reception on Thursday evening; a reception by the President of Harvard University on Tuesday evening; the usual banquet on the last evening of the Congress, and various excursions and entertainments for the ladies accompanying members.